THE SCIENCE OF HEALTH *and* DISEASE

A Textbook of Physiology and Hygiene

By

HOWARD W. HAGGARD

ASSOCIATE PROFESSOR OF APPLIED PHYSIOLOGY
YALE UNIVERSITY

WITH AN INTRODUCTION BY
YANDELL HENDERSON

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TO

PROFESSOR YANDELL HENDERSON

THIS BOOK IS DEDICATED

IN GRATEFUL RECOGNITION

OF HIS SERVICES IN

ITS DELIVERY

PRINTED IN THE U. S. A.

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INTRODUCTION

By Yandell Henderson

Medicine, together with religion, originated in magic. Until quite recent times it retained an occult character, which gradually became merely secret without supernaturalism, and finally only slightly secretive. I can remember, scarcely twenty years ago, asking a doctor who had given me a prescription for a cold, "What is it?" He replied that it was "Something to cure the cold." Even more recently I remarked of a certain disorder, from which an acquaintance was suffering, "Medicine can do little or nothing for it"; and this brought the reply, "True, but the doctor takes the responsibility!" Ignorance on the part of the layman was the psychological foundation on which the physician built that awe of his mysterious power which was supposed to be—and was in a sense—as important as the ingredients of his pills and elixirs.

Such an attitude is a thing of the past. It is immensely to the credit of the medical profession that it has thrown open all the portals of its knowledge. Anyone may enter and possess himself of all; nothing is withheld, or made in the least degree more difficult or mysterious than it is by nature. The physician and the surgeon pretend to no esoteric knowledge. They deserve and receive the highest respect, and render an inestimable service, not because they can describe a certain bone or bacterium better than a layman, but because they have acquired the practiced eye, the skillful hand, and the mind judicious in weighing a special type of evidence.

And yet much obscurantism persists. It persists particularly in what would be thought the least likely place—in education and particularly in medical education. It seems that the medical profession, and particularly the professors in medical schools and those instructors who go over to the college to give a course for undergraduates, are overwhelmed by the immensity of the details of medical knowledge. They cannot believe that the broad, gen-

eral, major matters in the science of modern medicine are of no greater volume, and of rather less difficulty, than those of such subjects as physics or economics. It is a subject of which any undergraduate student in college, or even in the high school, should be able to acquire the elements in a single course of three exercises a week for a year. The hard-driven medical student spends four years in arduous details. Even when he receives his degree and goes on to the hospital, or into practice, he still "cannot see the forest for the trees."

This book aims to "show first the forest" to anyone who wishes to see it. Every educated man should see it. For his own physical welfare and that of his family; for an understanding of what man is and his place in nature; for correct political opinions on the most important of all public questions, those of public health; for the profitable management of the employees whose working bodies, even more than factory buildings and machinery, produce the wealth of the industrialist; for all these reasons a broad understanding of the meaning of modern medical science, that is applied physiology, is as important as any element in education.

This book is intended particularly for three classes of readers:

First, it is for employers and engineers in charge of labor. It aims to give them a practical understanding of what the human body is, how it may best, most productively and profitably be utilized as a part of industrial machinery, and how by conserving it the charge on industry for worn-out and injured human bodies may be reduced to a minimum.

Second, it is a textbook for college students. It aims to afford them a general acquaintance with medical science, physiology in its broadest senses and applications, of a grade suitable for junior or senior year. In the form of lectures and a syllabus for student reading the material here presented has, in fact, been used for some years past for undergraduate students in a large elective course, under the title Industrial Physiology, in Yale University.

Third, this book is a broad survey of the whole field of modern medicine such as should be given in the initial course in the medical school. Years ago when the sciences of anatomy, physiology, and pathology were still newcomers in the medical curriculum, it

was considered necessary to keep the first few terms wholly clear of interest in the applications of these sciences to clinical matters. But now the medical sciences will rather gain if the student is first given a broad survey, so as to see to what practical uses the theoretical subjects, even in their now nonpractical aspects, may ultimately lead.

Finally, I would commend this book to the whole educated public. It was never so true as now that "the proper study of mankind is man." Modern science has destroyed that essentially theological universe in which on the sixth day Creation culminated in the production of the human body, and in which that body was regarded as merely a temporary habitation for a noncorporeal soul. Even if the Fundamentalists should succeed in binding education to their dogmas, and even if the Anti-vivisectionists, Anti-vaccinationists, and others of their kind should have their way, the result would not be a return to the historically beautiful, but in reality disease and superstition ridden, "age of faith." It would be rather the beginning of the end of civilization.

Nevertheless, the minds of educated men today stand shivering in a universe of inconceivable immensity. Something within us cries out for the basis of a new philosophy by which mankind can live. We must have courage to face the truth, for if it is not based on truth no philosophy of man's mission and fate will meet the test of practical application. To such a philosophy all the sciences must contribute, but none of them brings a more important truth than physiology. It tells us first what man is: Man is an animal. Until quite recent times he was as helpless before nature and its diseases as any other animal. Now modern science is making him master of his own fate. But it does so only on condition that he obey the ancient commandment of the Delphic Oracle, "Know thyself."

THE SCIENCE

OF

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CHAPTER I

THE HUMAN MACHINE AND THE SOURCE OF ITS ENERGY

The human body is an energy-transforming machine; it is what engineers call a prime mover. Carbon and hydrogen, which are the combustible elements of the food, are burned in the body and the chemical energy thus liberated is transformed into physical work and heat.

Life is inseparably connected with the expenditure of energy. When the body ceases to move and no longer produces heat, it is dead. All forms of living matter possess in common the fundamental property of transforming energy. The activities of all living things, from the most elementary to the most complex, are expressions of this fundamental property.

Elementary Structure.

The body of a man is not homogeneous but is composed of a multitude of individual and minute units. Each of these microscopic units is a living entity, each possesses the ability to transform energy, and if taken from the body and kept under suitable conditions can continue to exist and perform independently the fundamental activities of life. Each of these unit workers of the human body is called a cell. There are many living organisms, both plant and animal, which consist of only a single microscopic cell—the common yeast, for example. A cake of yeast consists of a mass of single cells, each one a living organism, with virtually the same fundamental vital properties as the human body. A yeast cell placed in a solution of sugar and water burns the sugar, liberates carbon dioxide, and generates heat; similar organisms may also move.

The body of a man and a cake of yeast have ultimately the same elementary structure; each is an aggregation of cells. Al-

though the cells of which they are composed have the same fundamental properties, the difference in the character of the activities of a man and a cake of yeast are tremendous. These differences are due to the specialization and coöperation of the cells which compose the various parts of the human body. A unicellular organism is like a man working entirely for himself with no relation to other men; the body is like an army or an enormously complex factory. An isolated man must make his own clothes, hunt his own meat, raise his own vegetables, carry his own water, and hew his own wood; in short, perform all the activities necessary for his maintenance. Owing to this diversity of activities his effectiveness in any one line is limited. In a great factory, on the other hand, the workers are specialized and they work together to common ends. Similarly, in the human body there are many groups of workers, the various types of cells, and each group performs a particular function for the body as a whole and for the other groups of cells, which, profiting by this service, can devote themselves intensively each to a specialized function of its own.

Differentiation of Cellular Structure and Specialized Properties of the Tissues.

Tissues are the materials of which the body is constructed. Each tissue is a group of cells differentiated to a particular type of structure which fits them to perform a specialized function. There are only a few basic tissues, although each may show variations; taken in various combinations, they compose all the organs of the body. They are muscle, bone, and fat, and the epithelial, glandular, nervous, and connective tissues.

Muscular tissue is made up of elongated spindle-shaped cells; each possesses to a high degree the power to contract along its long axis into a shorter and broader spindle. The physical work of the body is done by the muscular tissue.

Bone is a very dense, hard tissue, for its cells deposit lime salts. The bones form the framework of the body, the skeleton, and are the levers through which the power of the muscles is applied.

Glandular tissue is specialized to perform complex chemical transformations such as those by which milk is produced by a cow

fed on grass or grain. Other glands secrete fluids such as saliva, sweat, the digestive juices, and urine.

Epithelial tissue forms the covering for the surface of the body. The skin is composed of epithelial tissue, the outer layers of which are made more resistant to injury by a coating of cells which have been transformed into keratin, the material which also makes up hair, finger and toe nails, and horn.

In the fatty tissue the cells are filled with droplets of oil. This tissue thus affords a store of fuel which is given up when the food is insufficient to supply all the energy needed by the body. Fat, a large part of which lies just under the skin, also serves as a heat-insulating coat. It is similar in its function to the layer of asbestos around a steam boiler.

Nervous tissue is composed of nerve cells from which slender fibers extend to interlace with extensions from other nerve cells or make contact with cells of other kinds of tissues; it serves as a kind of switchboard to and from which nerve fibers are stretched like wires to connect with and control all parts of the body.

Connective tissue consists of innumerable minute but strong fibers which permeate and bind together the various structures of the body and act as a supporting frame for all other tissues. This tissue is also the material of which the tendons connecting the muscles to the bones are composed.

Organs of the Body.

It is of these tissues that the organs of the body are composed. Each organ may be thought of as a relatively independent machine; each performs a special service for the body. In this respect they may be compared to the magneto and carburetor of an automobile, the governor of a steam engine, or the water pump of a boiler. Just as these mechanical devices are made up of different metals, so the organs are composed of various tissues.

The heart, the liver, and the intestines are some of the organs of the body. The heart is a hollow bulb of several chambers; it is composed mainly of muscular tissue and serves as a pump to circulate the blood through the blood vessels, the system of pipes of the body. The liver is composed of gland cells supported in a framework of connective tissue. This organ secretes a fluid used in the

digestion of food, and is a storage depot for sugar. The intestines are in the form of a tube of which the walls are muscular tissue lined with epithelial tissue and covered with connective tissue.

The organs just mentioned are regulated unconsciously—that is, automatically or involuntarily. The construction of one of the parts of the body which is under conscious control may be illustrated by the arm and hand. In the center of the arm a series of bones are placed end to end and held together by ligaments of connective tissue. The bearing surfaces, or joints, are lined with connective tissue in a form called cartilage. About the bones are bundles of muscular tissue. Each muscle cell is held in a sac of connective tissue. Minute cords of connective tissue are fastened to each end of these sacs. The cords are collected into cables, the tendons. The tendons from the ends of the muscle are fastened to bones on opposite sides of one or more joints. Contraction of the muscle pulls upon the tendons and through them moves the bones, as levers, on the joint which acts as a fulcrum. Over the muscle is an insulating layer of fat, and upon this a layer of connective tissue which in turn bears the skin. Glands which secrete sweat, and others which secrete oil, have openings through the skin and pour their secretions upon the surface. Blood vessels, which are tubes of connective and muscular tissue lined with epithelial tissue, ramify through the tissues of the arm and supply them with nutriment and carry away the end products of their action. Nerves run to cells of the tissues and carry to them impulses which control their action. The nerves also carry impulses, which we feel as sensations, from the skin, muscles, and joints to the spinal cord and brain.

Systems of the Body.

A group of organs working together to effect some particular function in the body is called a system. The alimentary system, circulatory system, and nervous system are examples of this functional grouping of organs. The alimentary system, consisting of the mouth, stomach, intestine, and such glands as the liver and pancreas, is concerned with the preparation of food for absorption into the blood. The circulatory system, consisting of the heart,

the blood vessels, and the blood, has as its function the transportation of material from one part of the body to another. The nervous system, consisting of the brain and spinal cord, the nerves, and the sense organs, serves to regulate and direct the activities of the other organs, so that all parts work together and the body acts in relation to its environment.

The respiratory system, consisting of the lungs and respiratory passages, brings oxygen to the blood and also affords a channel of egress for the carbon dioxide which arises from the combustion of oxygen and fuel within the tissues. The urinary system, consisting of the kidneys, bladder, and urinary passage, has a function complementary to that of the respiratory system. It affords an egress for solid waste materials; the respiratory system affords an egress for gaseous waste materials. The muscular system furnishes the power for all movements of the body. The movements exerted through the bones and joints are most apparent but not the most important. Such movements serve to carry the body to its food or away from its enemies. There are in addition the movements by which the internal activities of the body are effected, such as by those of the heart and blood vessels. The reproductive system furnishes the means whereby the species is perpetuated through the formation of new organisms.

Food.

Food is the fuel which supplies the energy to operate the human machine and to replace the wear and tear of the tissues. Bread and butter, meat and vegetables, bear the same relation to the body that coal does to a steam engine or petroleum to an internal-combustion motor; but in addition they serve as the material out of which the body grows, and the engine itself is repaired.

As scientifically defined, the term food or, as we shall use it here, the "foodstuffs" composing food, has a broader meaning than merely that of fuel for energy. The foodstuffs include all substances which, when taken into the body, are used in any of its functions. This definition embraces a large number of materials which are indispensable to the body, although no energy

is derived from them. Water, vitamins, and a variety of mineral substances are all classed as foodstuffs. There is no term dealing with machinery which is exactly comparable to the word foodstuff as it is used here. Such a term would be some generic name covering, in addition to fuel, such items as lubricating oil, anti-scale mixtures for the boiler, iron and copper for replacing burned out parts, and in general a supply of the materials of which the engine itself is composed.

One basis for estimating the importance of any particular foodstuff is the length of time that the body can continue to live after being deprived of it. Men have fasted for periods of forty to sixty days. The result is a large loss of weight, for when no fuel is supplied the body burns its own fat, which has been stored away against just such a lean period. Deprivation of water is more serious than deprivation of food. The body is two-thirds water, but it has no large excess and the outgo is continuous. Less than a week of complete deprivation of water is fatal. Oxygen is the most important foodstuff when judged by the length of time deprivation can be tolerated, for when the supply of air is shut off, as, for example, by drowning, death results within ten minutes.

Fuel Foods.

The human machine derives its energy from the combustion of carbon and hydrogen, but neither of these elements in the free state can serve as a food, for the body is not equipped to burn them. Neither can they be utilized in all of their combined and combustible forms. Petroleum is an excellent fuel, but it cannot be utilized as such in the body, for it passes through the digestive tract undigested and unabsorbed. It is primarily upon digestibility that the relative values of various substances as fuel foods depend. To be available for the vital activities of the body, a fuel food must first be converted by digestion into a soluble form which can be absorbed from the alimentary canal into the blood. Digestion in man, as will be seen in a later section, is capable of rendering soluble and absorbable only a limited class of combustible substances: the carbohydrates, fats, and proteins. These substances constitute the fuel foods of the body.

Carbohydrates.

Sugars and starches constitute the class of carbohydrates. For the most part, they originate in plants. The sugar of milk is an exception, for it is formed in the animal body. Carbohydrates furnish the bulk of our diet, for they are the main foodstuff in potatoes and other vegetables, and in the cereals and cereal products such as flour, oatmeal, cornmeal, and other grain products. As their name implies, carbohydrates are composed of the three elements—carbon, oxygen, and hydrogen. The carbon alone is combustible, however, for the hydrogen and oxygen are present in the proportion which forms water; that is, every carbohydrate contains exactly twice as much hydrogen as oxygen. This fact can be seen in the chemical formula of such a typical carbohydrate as cane sugar, $C_{12}H_{22}O_{11}$. Here the hydrogen is already oxidized and only the carbon can be burned. During the process of digestion the carbohydrates are converted to the simple sugars such as glucose or grape sugar, and absorbed in that form.

A gram of sugar or starch burned in a calorimeter liberates approximately 4.1 kilocalories of heat (8,300 B.T.U. per pound).[1] When burned in the body it liberates the same amount of energy in the forms of work and heat.

Fats.

Fats are obtained from both animal and vegetable sources. Lard, suet, and butter are typical animal fats, while olive oil, cocoa butter, and cottonseed oil are representatives of the vegetable type.

Judged by their appearance and physical properties, there are nearly as many varieties of fats as there are sources from which they come. Regardless of their apparent differences, fats are

[1] Energy can be converted from one form to another; heat, electricity, and mechanical work, which are all forms of energy, can be measured and expressed quantitatively in common units. The heat unit or calorie is used for this purpose. A calorie is the amount of energy, as heat, required to raise 1 cubic centimeter of water (1 gram) through 1°C and is expressed by the symbol c; the kilocalorie is 1,000 of these units, is expressed by the symbol C, and is the term used throughout this book. The B.T.U. (British thermal unit) is the amount of heat required to raise 1 pound of water 1° F; it is approximately equivalent to 4 kilocalories.

essentially alike. They are all organic salts or, more correctly, esters of glycerine. Glycerine is an oily substance, but soluble in water, a triatomic alcohol which has the chemical formula $C_3H_5(OH)_3$. It is largely employed in the preparation of high explosives such as nitroglycerin. When glycerine is combined with palmitic acid, $C_{16}H_{31}O_2$, the fat palmitin is formed. The acid replaces the three hydroxyls, $(OH)_3$, of glycerine and the substance has the formula $C_3H_5(C_{16}H_{31}O_2)_3$.

Most vegetable and animal fats are mixtures of stearin, palmitin, and olein, deriving their names from the acid in combination with the glycerine. The melting point of the first two (when separated) is above the temperature of the body, while pure olein is liquid at ordinary temperatures. The melting points of the common fats are dependent upon the proportion of olein which is in the mixture. From observation of butcher's meat we are accustomed to think of animal fat as a solid material, but in reality it is melted at the temperature of the living body and exists there in the fluid state, in minute globules within the cells.

During the process of digestion three molecules of water are added to each molecule of fat, which is then split into its component parts—three molecules of fatty acid and one of glycerine. The soapmaker carries out essentially the same procedure. He separates the glycerine and acid, removes the former, and combines the acid with sodium of potassium. Soap is different from fat in being the alkali salt of oleic, palmitic, or stearic acid instead of the glycerine salt. Although the body could derive energy from soap, the corrosive action of the alkali prohibits its use as an article of diet.

When fat is burned in the tissues of the body, both the carbon and hydrogen unite with oxygen taken from the air to form carbon dioxide and water. Fat has the greatest heat content of any of the fuel foods. On combustion, one gram of fat liberates 9 kilocalories of heat (19,000 B.T.U. per pound).

A man whose diet contains olive oil, or lard, or butter in excess of his immediate energy needs, stores the excess as fat. The fat of the human body differs in appearance from the ordinary fats of the food and is, in fact, a different mixture of palmitin, olein, and stearin. In forming and storing fat, the

body selects from the fats of the food the proper proportion to make human fat. If fat is eaten in great excess, and particularly if it is largely of one variety, some of the fatty acids characteristic of human fat may be lacking and typical human fat cannot be formed. The fat stored under such circumstances resembles the fat eaten.

Proteins.

Proteins bear a more intimate relation to the body than do the other fuel foods. They constitute an essential vital constituent of the body cells. The service of proteins as fuel foods is subsidiary to their important functions in growth and replacement of the tissues. A supply of proteins in the diet is therefore necessary for the maintenance of the body; but an excess of proteins in the diet is an expensive and physiologically uneconomical form of fuel. The flesh of animals, chiefly muscle tissue, forms the main supply of protein in the diet; vegetable proteins are not satisfactory as a complete substitute.

Proteins contain nitrogen and sulphur and sometimes phosphorus in addition to carbon, oxygen, and hydrogen. The percentages of these elements in proteins vary within narrow limits; the average composition is as follows:

Carbon	52 per cent
Hydrogen	7 " "
Oxygen	23 " "
Nitrogen	16 " "
Sulphur	2 " "

The chemical composition of proteins is exceedingly complex. They are built up of groups of interconnected amino acids. An amino acid is an organic substance containing a varying number of atoms of carbon and hydrogen, and is characterized by containing in addition the basic group, $-NH^2$, and the acidic, $-COOH$. One of the simplest, glycocol, or amino acetic acid, has the formula $CH_2(NH_2)COOH$. The various amino acids which combine to form a protein are linked together with the acidic radicle of one connected to the basic radicle of the next.

The structure of a protein may be compared to a mosaic pat-

tern in which stones of many colors and shapes represent each a particular amino acid. The same stones could be arranged in a great variety of patterns and each pattern would correspond to a separate and distinct protein. The introduction of an additional colored stone into the pattern would greatly increase the number of the possible combinations. The differences between the proteins in the protoplasm of the cells of the horse, man, cow, and other animals are due to the patterns in which the amino acids are arranged and to some extent to the varying number of the different amino acids in the protein molecule. Likewise in plant proteins the patterns differ from those of animal tissues; some amino acids which go to form the flesh of animals are not present in some vegetable proteins, a point which is important from a dietary aspect.

The digestion of proteins consists in the disintegration of the molecules into their component amino acids. These are then absorbed into the blood, rearranged by the body, and built into new proteins having the characteristics of those in the protoplasm of man. If the protein eaten is deficient in one or more of the amino acids necessary to the pattern typical of the protein in human protoplasm, it cannot be reassembled in the form of human protein. Unless the diet is altered, the maintenance of tissue repair and growth suffers.

Proteins are not burned completely in the body as are carbohydrates and fats. The nitrogen which the proteins contain is split off as urea. Thus some of the carbon and hydrogen which otherwise might be burned completely is eliminated through the urine. Proteins when burned in the body give rise to approximately the same amount of heat as an equal amount of carbohydrates; when burned outside of the body they give rise to more heat (see Chapter IV).

CHAPTER II

DIGESTION AND ITS DERANGEMENTS

THE unicellular organisms referred to in the previous chapter obtain their food by absorption through the surfaces of their bodies; to live they must be immersed in food. The same is true of the cells which constitute the more highly organized human body. Every living cell in the body must have in the medium about it at all times the material from which it effects its energy transformations. The cells of the tissues of the human body live in the same relation to the blood, lymph, and tissue fluid that unicellular organisms do to the water of the sea or lake or pond from which they absorb their nourishment.

The fuel foods, as they exist in the ordinary diet, are of complex form which cannot be utilized directly by the cells of the body. By the process of digestion these foods are reduced to the simple and soluble state necessary for their absorption into the body and for their utilization by the cells. These alterations are accomplished during the passage through the digestive tract. This tract is a long convoluted tube extending from the mouth to the anus. There are no open communications from it into the substance of the body; the material absorbed is first dissolved in the digestive fluids and then diffuses through the walls of the tube into the blood. The circulating blood carries the dissolved material to all of the cells of the body.

Material which lies within the digestive tract is, strictly speaking, outside of the body. The body may be considered as a double-walled tube, the outer surface covered by the skin, and the inner surface by the absorbent membrane of the gut. The inner and outer surfaces meet at the mouth and anus, while the body proper fills the space between. The digestive tract is like a tunnel built through a factory. The material brought into this tunnel is sorted and refined, and the usable material is passed into the factory.

Digestion as a whole resembles the general procedure employed

in the chemical industries for extracting substances from raw materials. The movement within the digestive tract is analogous to that of a conveyor system such as is used in factories to transport material from place to place in the course of its manufacture. The crude materials enter the hopper at the top of the

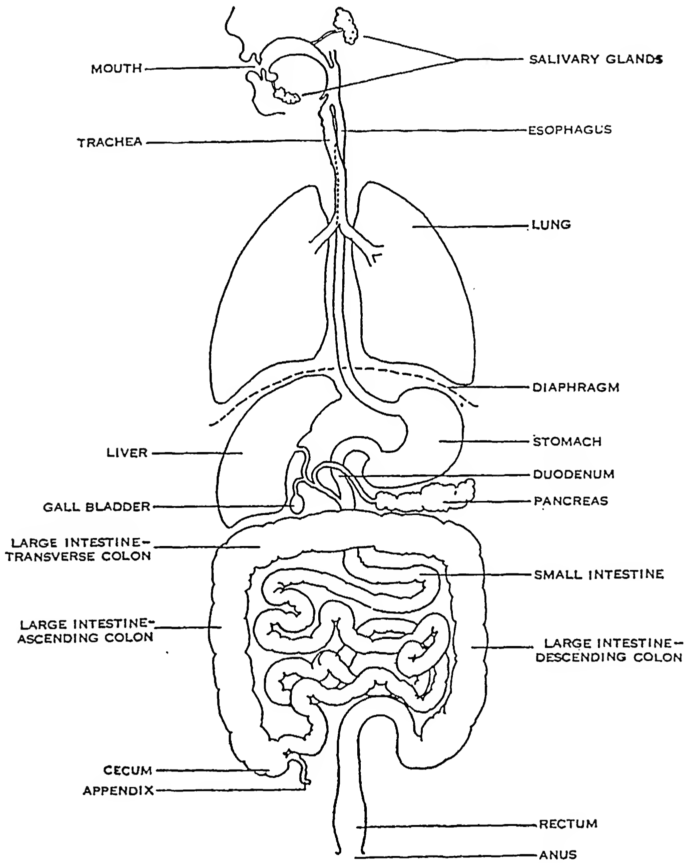

Figure 1. Schema of Alimentary Tract.

conveyor and are subjected to mechanical division by a crusher which we call the jaws and teeth. The finely divided material is carried by the conveyor to the stomach, a reservoir, where it is treated chemically and churned into a thin gruel, after which it is passed along gradually. Leaving the stomach, the partially digested material is passed through the small intestine, a narrow

tube some thirty feet long, where it receives further chemical treatment and the dissolved material is filtered off into the blood. Finally the wet indigestible residue is collected in the large intestine, another reservoir, where the water is extracted and recovered for further use and the waste is concentrated as feces, to be discharged by defecation.

The above is a general view of the process of digestion. We now turn to a detailed consideration of the various steps involved.

Chemical Digestion.

The division of food by the teeth is the only mechanical comminution exerted during digestion; the remainder of the process is accomplished by chemical action. The chemical agents concerned are known as ferments or enzymes. Enzymes are substances, presumably of protein nature, which, when present in small amounts, are capable of inducing specific chemical changes without involving any appreciable expenditure of energy and without themselves undergoing alteration. They are catalytic agents and expedite chemical reactions. The action of each enzyme is specific; for example, one reduces starch to maltose, while another splits proteins into their component amino acids. These enzymes are formed in the glands which produce the digestive fluids.

Cooking as an Aid to Digestion.

Man is omnivorous, that is he eats all types of food, but his teeth and the movements of his jaws are less effective on each variety of food than are those of animals which are either exclusively carnivorous or herbivorous. Raw meat and cereals, uncooked and unground, are incompletely utilized by man; but if cooked, so that they are softened, they can be readily masticated.

Digestion commences in the kitchen. Materials which, if raw, would be attacked with difficulty, are rendered easily digestible by cooking; the boiling or roasting of meats softens and swells the fibers and thus makes them more permeable to the digestive fluids. An indigestible membrane of cellulose surrounds the starch grains of cereals and vegetables; this capsule is ruptured by cooking and the liberated starch is changed to a soluble form.

Digestion in the Mouth.

The next stage of digestion is in the mouth. It consists in dividing the food mechanically by the teeth and mixing it with the saliva. In mastication, or chewing, the food is pushed between the teeth by the tongue and cheeks and ground up by the lower jaw acting against the upper under the force of powerful muscles. The movements involved in chewing are intermittent. During the time when the lower or movable jaw is relaxed, the tongue and cheeks coöperate in bringing new or incompletely masticated portions of food into position to be crushed during the period of closing. Normally, mastication is continued until the food mass is reduced to a finely divided moist state which is suitable for swallowing.

The mastication of food is an extremely important step in digestion. Improper mastication leaves the food in masses of a size not readily accessible to the digestive fluids. This results in slower and less perfect digestion and in irritation of the digestive tract. Other than mastication, the digestive processes are involuntary and when once initiated are beyond the control of the will, although readily affected by emotions. Mastication is subject to much neglect from the habit, either nervous or environmental, of bolting food. Much of the so-called "indigestion" is not due to any disorder of the stomach, but arises from the difficulty with which a normal organ acts upon material inadequately prepared.

Teeth and Gums.

It is impossible to masticate solid food properly unless the teeth and gums are healthy. An adult man or woman is normally provided with sixteen teeth in each jaw, or rather fourteen, as the "wisdom" teeth are seldom perfect. These are the permanent teeth, so called to differentiate them from the temporary or deciduous teeth of childhood. (The eruption of the deciduous teeth is discussed in Chapter XXIII.) The four front teeth in each jaw have incisor edges suitable for biting off or gnawing the food. The three molar teeth in the back of the jaw on each side are broad and have grinding surfaces. The canine and

bicuspid teeth, which are between the incisors and molars, are intermediary in character and function. In carnivorous animals the canines are the principal weapon of offense and are used for tearing flesh. When a man is angry he draws up his upper lip, and this snarl exposes the canine teeth, just as in the beasts which fight with their teeth.

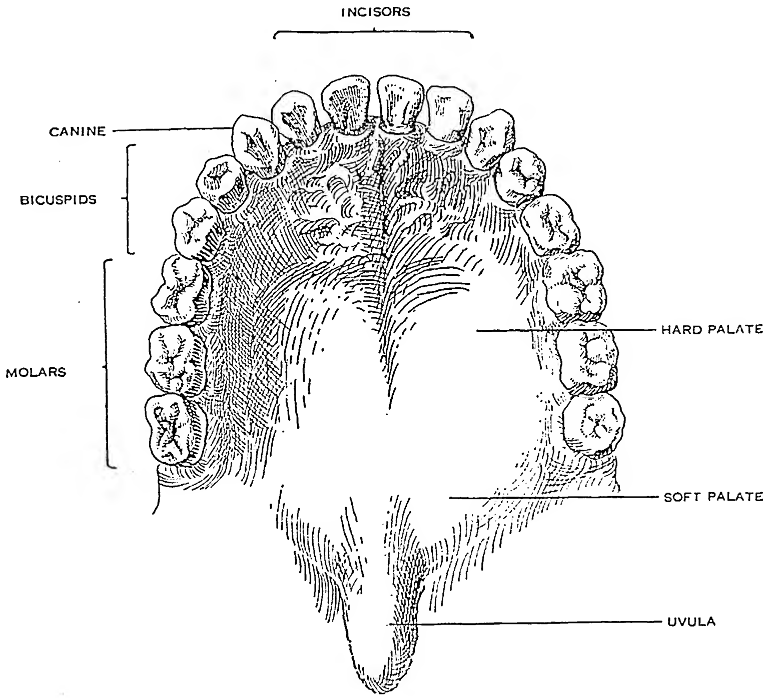

Figure 2. Upper Dental Arch and Palate.

Firmness is given to the hard palate by the plate of bone above it, shown in figure 7. The soft palate terminates in the conical structure known as the uvula, which is shown in front view in figure 19.

The incisor teeth of the upper jaw are wider than those of the lower, with the result that every tooth in the lower jaw, with the exception of the incisors, is in relation with two teeth in the upper jaw; consequently the teeth of the two jaws mesh together, the projections, or cusps, on the surface of the teeth of one jaw fitting into the depressions in the teeth of the other. A slight lateral movement of the jaw thus results in an effective grinding of food placed between the molar teeth. In most individuals the

incisor teeth of the upper jaw are set farther forward than those of the lower. This overlapping of the incisor teeth gives a shearing action in biting off food.

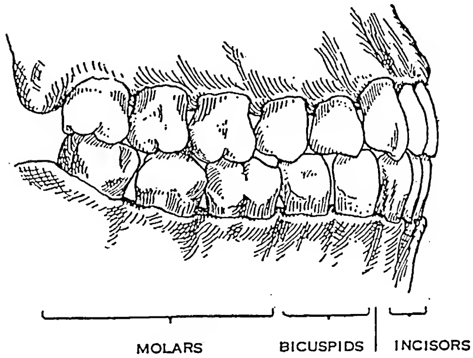

Figure 3. TEETH OF UPPER AND LOWER JAWS IN APPOSITION.

Abnormal Position of Teeth.

The conformation in which the teeth of the upper and lower jaw meet, the "bite," is of great importance in relation to the preservation of the teeth. An incorrect conformation results in lateral pressure upon the teeth when the jaws are brought together. In consequence of this pressure the affected teeth are moved in their sockets; the junction between the teeth and the gums is widened, and pockets are formed which retain food. The irritation arising from this retention of material contributes to the development of pyorrhea alveolaris. Incorrect apposition of the teeth can usually be corrected in childhood by metal braces which slowly pull the teeth into their normal positions.

It is likewise in childhood that the abnormal position is commonly developed; as a result of thumb-sucking, for example, the upper central incisors are forced outward; or as a result of adenoids the hard palate is altered in shape, and the teeth of the upper jaw are thrown out of alignment with those of the lower. Heredity also plays a large part in determining the arrangement of the teeth; if a small jaw is inherited from one parent while large teeth are inherited from the other, crowding and abnormal alignment result. Likewise the premature extraction of the temporary teeth, sometimes necessitated by decay, interferes with the

proper development of the jaw and the spacing of the subsequent permanent teeth, causing them to crowd.

Structure of a Tooth.

Each tooth consists of a crown, neck, and root or roots. The crown is the portion which projects above the level of the gum, the neck is the constricted portion embraced by the gum, and the root includes the remainder of the tooth which is buried in the jawbone.

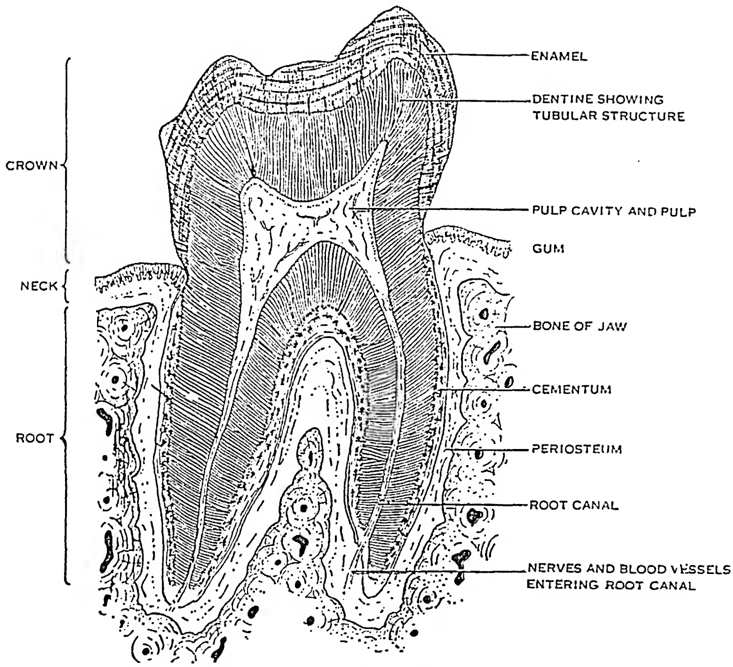

Figure 4. Longitudinal Section of Normal Tooth.

A tooth is composed principally of dentine or ivory. A layer of hard enamel covers the dentine of the crown, while that of the roots is coated with cement which serves to join the tooth to the jawbone. In the center of the dentine is a small cavity which opens at the tip of the root for the entrance of blood vessels and nerves which form the pulp filling the cavity. The dentine is channeled by a multitude of minute tubes which by their inner ends communicate with the central cavity and extend outward to the enamel. These tubules of the dentine are really extensions

of the central cavity and are filled with the same pulp material. A tooth is a living structure which is permeated by soft flesh-like material.

Unlike other structures of the body, a tooth does not repair itself after injury. When the skin is broken, healing takes place and a new layer is formed, but when the enamel is removed from a tooth it is not restored. When the dentine is exposed the delicate proliferations of the pulp in the tubules of the dentine are laid bare, and there is then as much an opening into the flesh as in a sore on the surface of the body. An open wound on the skin is of no serious consequence if it can be kept perfectly clean. It is impossible to keep the mouth clean even with the greatest care; only a small proportion of the population use tooth brushes and dental floss, which at best do not effect perfect cleansing. A decaying tooth is an infected wound.

Decay of the Teeth.

The course of events in decay is in general as follows: The enamel is broken down, usually from lack of cleanliness, although other conditions contribute. Particles of food remain between or about the teeth and undergo fermentation and putrefaction, and the products corrode the enamel. The dentine in the exposed area becomes discolored and eroded, and the tubules leading to the pulp cavity are invaded by bacteria. The tooth may then become painfully sensitive to heat or cold or salt or sugar, which irritate the pulp within the tubules of the dentine. It is at this stage, or better even before, that the remedial act of filling teeth produces the best results. The decayed dentine is carefully removed, the clean surface coated with an insulating cement, and the cavity filled with gold or an amalgam or other suitable stopping material. If this treatment is neglected a third stage of decay is sooner or later reached: the dentine is eroded until the pulp cavity is exposed and infected by bacteria.

Dead Teeth and Infection.

Inflammation follows the invasion of the pulp and causes severe toothache which may last from a few hours to days or weeks. When a tooth has once ached for any lengthy period, thus show-

ing that the pulp is involved, the time for really saving the tooth has passed. To fill such a tooth it is necessary to kill it by removing the nerve and plugging the central cavity and its extension into the roots. By so doing all nourishment is removed from the crown, and the root is supplied only from the outside by the vessels which line the socket. A devitalized and properly filled or crowned tooth may last for some years, but in the best cir-

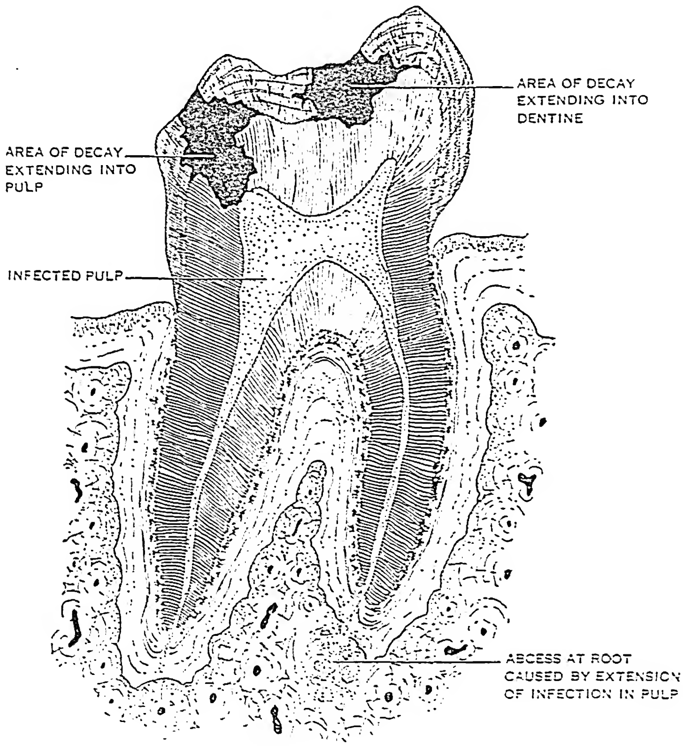

Figure 5. Longitudinal Section of Decayed Tooth.

cumstances it is a foreign body, a more or less clean splinter of dead bone projecting into the jaw which at any time may become the seat of infection. Moreover, no pain or other symptoms referable to the tooth may arise from such infection. Its source is then difficult to locate.

A tooth which has decayed into the pulp cavity and is not treated, sooner or later forms an abscess. The pulp with its nerves and blood vessels dies and putrefies, and a mass of septic

material extends to the ends of the roots where it is in contact with the jawbone. Bacteria of many kinds grow in the material which collects in the cavity. Serious local effects usually do not develop so long as the root canal remains open and the septic material can drain into the mouth. Eventually the infected material is forced through the root and into the surrounding tissues either by the pressure of mastication or through plugging of the root canal. Pus forms in the jawbone and an abscess results.

When pus is formed and is prevented from draining freely to the surface, pressure results. The pus in an abscessed tooth may develop sufficient pressure to raise the diseased tooth slightly above the level of the others; the elevation is noticeable on biting and pressure applied to the tooth is painful. When pus collects under pressure the infection is spread; the products of bacterial action and the bacteria themselves are forced into surrounding tissues and even into the blood through which they are disseminated, giving rise to secondary infections in other parts of the body. Many serious general diseases are now attributed to infected teeth, such as rheumatism, insanity, diseases of the kidney and heart, to enumerate only a few. Fortunately only a small proportion of untreated persons develop these serious systemic diseases in direct consequence of dental caries, or decay, which is (after the head cold) the most common disease of man and probably has been so from prehistoric times.

Pyorrhea Alveolaris.

A common disease of the teeth is pyorrhea alveolaris or pus formation between the teeth and gums. This disease is primarily caused by a separation of the gum from the teeth, owing to the improper apposition of the teeth of the two jaws, or from the deposition of tartar about the necks of the teeth. Tartar is a mixture of calcium carbonate and organic material; it separates from saliva especially when breathing is done through the mouth. As a result of pyorrhea, the teeth are loosened in their sockets and the gums recede and bleed on pressure or even from brushing. The pus formation may be very extensive, and in consequence the breath is made foul and the health is impaired.

Hygiene of the Teeth.

The most easily combated cause of diseased teeth is lack of cleanliness, for the influence of diet (vitamines, etc.) is still obscure. When the food is coarse and fibrous it exerts a scouring action while it is being chewed which is lacking with most of the rich and concentrated modern diets. It is thus necessary to take active measures to prevent the accumulation of fermentable material about the teeth; the toothbrush and dental floss serve this function. In this connection it is notable that decay nearly always starts either on the top, between, or on the outer surfaces of the teeth and rarely on the inner surface which is swept clean by the tongue.

In certain occupations the enamel is worn from the teeth through contact with metal. This occurs in workmen who hold nails in the mouth to facilitate rapid work, as do shoemakers and those engaged in nailing lath or shingles. In other industries the enamel of the teeth may be ground away by sharp particles of dust which enter the mouth. Such substances are graphite, coarse metal dust, sand-blast material, and the like. In sugar refineries the inhalation of sugar dust leads to rapid decay.

Lead and mercury have a detrimental action upon the teeth which leads to pyorrhea, as in plumbers, typesetters, painters, and pottery and metal workers. Those who work with phosphorus are exposed to a particular danger unless their teeth are kept clean and in excellent repair. The decay which results from phosphorus does not stop with the tooth or its socket, but involves the entire jawbone, causing so-called "phossy jaw."

The hygiene of the teeth is of great importance to industrial efficiency; diseased teeth contribute directly to ill health, while loss of teeth is followed by imperfect mastication and the ills which attend this condition. It has been found profitable by many large employers of labor to maintain a dentist or dental hygienist in the factory, and to supply dental service to the employees either free or at nominal rates. The office hours of most private dentists coincide with the working hours of the factory and it is difficult for the employees to leave their work and go for treatment. In trades which are by nature detrimental to the teeth, it is the duty of the employer to institute compulsory

dental examination and demand that the employees brush their teeth regularly. Finally, it must be remembered that a boy of twelve years is an adult so far as his teeth are concerned, and that for the sake of future employees, both on altruistic and on the most narrowly selfish grounds, it is to the employer's advantage that workingmen should carry into their homes the message of dental cleanliness.

Chemical Digestion in the Mouth.

The processes of digestion in the mouth are not entirely mechanical, for it is here that food comes in contact with the first of the digestive fluids, the saliva. In the tissues about the mouth there are six glands which pour the saliva which they secrete through tubes into the mouth. The main glands, the parotid, are located directly under the lobe of each ear; these glands are familiar as the site of mumps, in which disease they are swollen and painful.

The flow of saliva is stimulated by the presence of material in the mouth, while the amount and consistency of the fluid are determined by the nature of the substance exciting the flow. No saliva follows the introduction of water; but sour, bitter, or salty fluids, which must be diluted and washed away, induce a copious flow of thin and watery secretion. Similarly, dry but unappetizing substances such as sand, excite a profuse discharge of thin saliva which aids in their ejection from the mouth. If, on the other hand, the substance is edible, the saliva is viscous, while the amount secreted varies with the dryness of the substance. Sufficient saliva must be added to soften and lubricate the material in order that swallowing may take place.

To stimulate the flow of saliva in a person who has a keen appetite, it is unnecessary to place food in the mouth; the sight, smell, or even the thought of some savory substance will "make the mouth water." In the opposite manner, strong and disagreeable emotion such as fear and worry diminish or stop the flow of saliva even in the presence of stimulating substances. One of the earliest judiciary measures took cognizance of the suppression of salivary secretion by fear. The "ordeal" consisted in filling the mouth of the suspected person with flour; if he were

innocent the flow of saliva was normal and he masticated and swallowed the flour; if he were guilty his fear gave rise to an inability to moisten and swallow it. While this test is sound physiologically, it must have condemned many innocent persons of nervous temperament and have exonerated the guilty if bold.

Saliva contains an enzyme which has a digestive action upon starch, converting it into soluble and assimilable sugar. Little actual digestion of the starch occurs in the mouth, for the food does not stay there a sufficient length of time. The main salivary

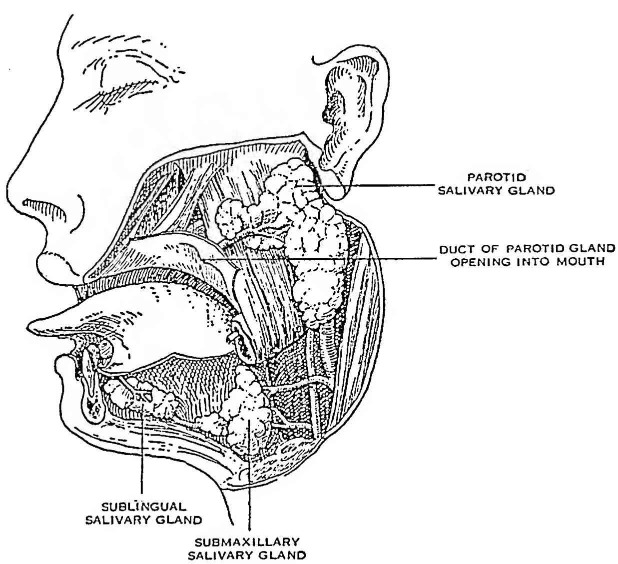

Figure 6. SALIVARY GLANDS.
Dissection of the face showing salivary glands of the left side.

digestion takes place in the stomach, where it continues until the food is rendered acid by the gastric secretion.

Swallowing of Food.

From the mouth and pharynx the food passes to the gullet or esophagus and down this into the stomach. The esophagus is a soft muscular tube whose function is purely one of transportation, since it plays no part in the chemistry of digestion. In the act of swallowing the bolus of finely divided food, saturated with saliva, is first gathered well back on the top of the tongue, the

edges of the tongue are next brought up tight against the roof of the mouth to prevent food from escaping back into the mouth; then a sudden upward and backward movement of the tongue projects the food into the esophagus.

Behind the mouth is the throat or pharynx and through this cavity the food must pass to reach the esophagus. Passages which lead to the nose and lungs also open into the pharynx. To prevent food from passing up into the nose, the soft palate rises during swallowing and occludes the nasal passage, and at the same time the windpipe or trachea is shut off by a lid-like flap which closes over the larynx so that the food is left but one channel to follow, that into the esophagus. Swallowed liquids are projected the full length of the esophagus under the impetus given them by the tongue. Solid foods are conveyed through the esophagus by wave-like constrictions, called peristalsis, in the wall of the tube.

On reaching the lower end of the esophagus the food passes a muscular valve which closes the opening into the stomach. Through this valve material passes slowly and more or less continuously in distinction to the intermittency of swallowing. As a result of hasty eating or swallowing large mouthfuls, food may accumulate in the lower end of the esophagus and give rise to an unpleasant sensation of fullness. Successive swallows of small amounts of fluid tend to hasten the passage through the valve into the stomach; this is the reason that many persons, who bolt their food, facilitate its passage by sipping water after each mouthful.

The passage of food through the esophagus is rarely interfered with except in the case of partial or complete occlusion of the tube by tumors or by scars following injury from corrosive substances such as strong alkalies or acids. Thereafter food can be administered only through an opening, made by surgical operation, in the anterior wall of the body and stomach. Aside from carbolic acid taken with suicidal intent, the most common agents causing corrosion of the esophagus are muriatic acid, used as a soldering flux, and household lye. Careless adults sometimes mistake the acid for a beverage; it is a common accident for small children to drink the strong solution of caustic lye used to clean

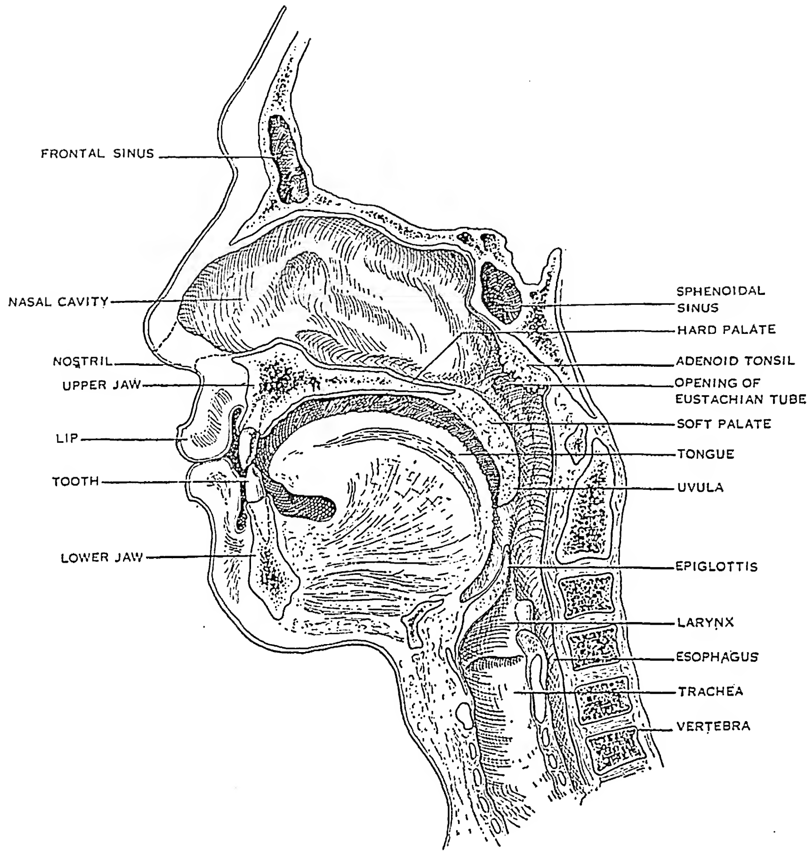

Figure 7. SAGITTAL SECTION OF HEAD.

The primary passages shown are the esophagus, leading to the stomach, and the trachea, leading to the lungs. At their upper ends the trachea and esophagus join to form a common passage, the pharynx, which opens into the mouth and nasal cavity. The common passage necessitates an arrangement through which food may be directed into the esophagus; this is accomplished by the act of swallowing. Except during swallowing the esophagus is closed by the apposition of its walls.

Passages lead from the nasal cavity into the middle ears (the eustachian tubes), and also into the sinuses. Although the frontal sinus is shown, the passage to it does not fall in the line of section; see figure 25.

The adenoid tonsil is shown on the rear wall of the nasal portion of the pharynx.

household drains. Warnings should be pasted on the cans in which household lye is sold.

The act of swallowing is complex, but its coördination is rarely disturbed. Occasionally, however, food or drink finds its way into the windpipe, usually as the result of talking or laughing during the act of swallowing. Any irritation in the windpipe at once excites coughing. The sharp blasts of air occasioned by this act usually remove the misplaced material. If the body lodged in the trachea is solid and bulky, death from strangulation may follow. An unconscious person cannot cough and may be strangled by false teeth or tobacco which may be in the mouth.

Function of the Stomach.

The stomach is not an absolutely indispensable organ of digestion, for the chemical transformation of the food which takes place there can be carried out equally well by the intestines. Life can continue and the essential minimum of digestion may take place after complete removal of the stomach. The unfortunate who has suffered this loss is seriously inconvenienced, since his diet is restricted to gruels which must be taken frequently and in small quantities. The stomach functions as a protective organ to the intestines. Its chief function is as a reservoir for large quantities of food taken at infrequent intervals; thus such animals as dogs, which eat a concentrated diet, may be fed only once a day.

Filling of the Stomach.

The stomach is a distensible muscular pouch and its size is determined entirely by the volume of food which is in it. In the morning before breakfast the stomach is contracted and contains only a few ounces of fluid and some bubbles of swallowed air. Shortly before the usual hour for breakfast, if no food is taken, the muscular walls of the stomach contract until the organ is little more than a tube. This active contraction of the stomach is associated with sensations of hunger. Food entering the stomach distends it and the stomach relaxes to hold the material, gradually assuming a shape sometimes compared to that of a pear. The larger end or fundus, lies to the left behind the lower ribs;

the esophagus opens into it. The smaller end to the right tapers into the small intestine at a point near the mid-line of the body. The opening into the small intestine, called the pylorus, is closed by a muscular valve which opens in response to suitable stimuli and allows the passage of food material, when suitably prepared, into the small intestine.

Food entering the stomach makes room for itself by stretching the walls. As the reception of food continues, each succeeding portion passes to the center of the mass already there, and as a result the food is deposited in layers. That which has been in the stomach the longest is in contact with the walls, from which

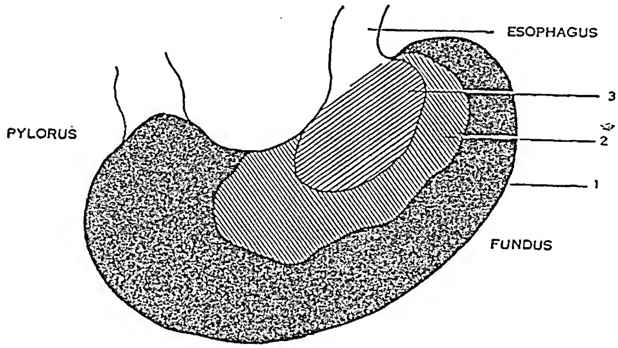

Figure 8. FILLING OF THE STOMACH.

Section of a rat's stomach showing stratification of food given at different times. The food was given in three portions, indicated by the differently shaded areas, in the order designated by the numbers.

is poured the acid digestive fluid, while the more recent additions are nearer the center of the mass. The esophageal end of the stomach, or fundus, is the most distensible portion and the bulk of the food material accumulates at this point and may remain from a half hour to two hours before it is rendered acid by the gastric juice. If mastication has been thorough and the food well mixed with saliva, salivary digestion continues in the center of the mass and most of the starch is there converted into assimilable sugar.

Movements of the Stomach.

As the food material in the stomach is brought in contact with the walls it is thoroughly mixed with the gastric juice. There

is never a general churning or mixing of the accumulated material in the fundus. The walls of this part of the stomach contract gently upon the mass and express the more liquid portions. In the pyloric end the movements are more forcible; the walls contract rhythmically in successive rings which travel as a wave-like movement toward the intestinal valve. With each wave the stomach walls meet near the outlet and form a pouch shut off from the rest of the stomach. By the contractions of the walls of this pouch upon the material which has collected in front of the intestinal valve, a pressure is developed sufficient to support a column of water a half meter high—that is, nearly a pound to the square inch. If the material under pressure is suitably prepared, the valve is released and the material squirted into the intestine.

Digestion and Absorption in the Stomach.

The walls of the pyloric portion of the stomach secrete a digestive fluid known as gastric juice. This secretion contains 0.2 to 0.4 per cent of hydrochloric acid and has in addition two important ferments or enzymes (or rather one with two actions), rennin and pepsin. Rennin acts to curdle milk and thus make a solid material more readily handled and separated from water. Pepsin digests protein material.

The influences which control the flow of gastric juices are similar to those which control the flow of saliva into the mouth. The taste, smell, or even thought of food may initiate the flow. Hunger thus increases the flow of gastric juice, while distaste, worry, fear, and other strong, unpleasant emotions diminish or prevent the flow. The introduction of food into the stomach is followed by a flow of gastric secretion and in this respect some foods have a much greater effect than others. Bread alone results in a very small secretion of gastric juice while meat, and more particularly the extractives of meat such as are found in soups, have a very pronounced secretory effect. Carbohydrates require very little gastric juice to render them acid, while protein material unites with considerable quantities of acid before the acidity becomes predominant. Even with the increased flow of gastric juice induced by meat, protein materials stay longer in the stomach than do carbohydrates. Fats have an inhibitory influence upon

the secretion of gastric juice; meals high in fats pass on from the stomach more slowly than meals low in fats. Furthermore, fats which are not melted at the temperature of the human body have a tendency to congeal about the food particles and prevent the gastric juices from reaching them.

Intense sweating reduces the acidifying and digestive powers of the gastric juice since the amount of secretion is diminished. Muscular exhaustion causes a decreased flow of gastric fluid and digestion may cease entirely under heavy muscular work. Poorly masticated or compact and improperly prepared foods are slow in becoming saturated with gastric juice and remain in the stomach for a longer time than do more porous foods.

Whether or not the stomach will empty itself completely of one meal before the next is taken depends upon the length of the interval between meals and the conditions affecting the rate at which food passes through the stomach. One of the factors is the amount of food taken; other things being equal, the larger the meal the longer it will remain in the stomach. Meals of approximately one-third of the daily food may not disappear entirely from the stomach under six or seven hours.

The absorption of food substances from the stomach is very slight as compared with absorption from the intestines. Pure water is not normally absorbed at all from the stomach, but is passed through rapidly to the intestines. Irritating substances such as spices, salt, and alcohol exert an influence to increase the absorption from the stomach. Condiments not only increase the absorption of assimilable substances, but increase to some extent the secretion of gastric juice. The habitual use of highly seasoned food or alcohol may lead to a condition in which the gastric juice is more acid than normally; the same condition may result from the irritation caused by poorly masticated food. This condition is usually accompanied by an ill-defined feeling of gastric distress and by constipation.

Gastritis.

The stomach is a remarkably efficient organ and usually fulfills its functions with little indication of its presence. The tolerance of the stomach, however, is frequently abused by irritating

substances taken in the diet. As a result a so-called simple acute gastritis is developed and may exhibit any degree of severity in its local and general effects from the "green-apple stomachache" of youth to the prostration of ptomain poisoning. The general state of health and such conditions as hot weather or hot work-rooms have some influence upon the tendency to develop acute gastritis. The direct cause may be one of many: coarse and indigestible food, excess of food after a prolonged fast or fatigue, food or drink at extremes of temperature, corrosive substances such as acids or alkalies, the salts of heavy metals, alcohol, spices, and many drugs. Perhaps the most common cause is tainted food which is rendered irritating either from the products of previous bacterial action or from the action of the bacteria after they reach the stomach. Repeated acute gastritis of moderate severity may lead to chronic gastritis. Its most common cause is the habitual use of alcohol.

Food Poisoning.

Foods may be poisonous because of some active drug-like principle which they contain, as in some mushrooms, or they may be rendered poisonous by putrefactive changes resulting both in poisonous material and in harmful bacteria. The flesh of diseased animals may contain the organisms of tuberculosis or trichinosis; these organisms cause infection, if the food is insufficiently cooked. Other foods may become infected with bacteria such as that of typhoid fever, and so convey the disease.

A common form of food poisoning occurs from eating meat contaminated with bacteria closely resembling those which cause typhoid, the so-called paratyphoid organisms. In severe cases the symptoms come on in a few hours: vomiting, purging, pain in the abdomen, and sometimes collapse and death. Individuals react very differently to this type of food poisoning and the same epidemic may show every grade of severity from a headache with slight fever to death. A recent group of cases among college students was traced to a cook who was a paratyphoid carrier (see Chapter III). The important matter in connection with this type of poisoning is the unaltered appearance of the infected food, for it has not undergone putrefaction; it is simply contaminated. It

can be rendered harmless by thorough heating at the temperature of boiling water. But it must not be handled thereafter, for it may be reinfected.

Poisoning which occurs from eating meat which has undergone evident putrefactive changes is caused by the toxins produced by the action of bacteria. This type of poisoning is usually called ptomain poisoning. Strictly speaking, however, ptomain poisoning is poisoning by certain basic alkaloidal products—ptomains—formed during the putrefaction of certain proteins, especially those of shell fish; but the term has been popularized and is now often used to denote all forms of food poisoning.

Botulinus Poisoning.

Food poisoning from the toxins formed by the bacillus botulinus is particularly severe and is almost always fatal. The usual source of this poison is canned goods imperfectly sterilized at the time of packing. A "flat, sour" taste and faint odor are the only indications of the putrefactive change in the material. A drop of the fluid from the food placed on the tongue and washed off, but not swallowed may cause death. The appearance of the can often gives an indication of the spoiled contents. The normal vacuum is lacking, the ends of the can are bulging instead of slightly concave, and pressure applied to the end elicits a sharp sound as the tin bends inward. A can in the condition described is known as a "bloater" and the contents should be disposed of in a manner to prevent the consumption by domestic animals, for they, as well as man, are susceptible to botulinus poisoning. The toxin of the bacillus botulinus is destroyed by heating for several minutes to the boiling point. It is advisable to boil all canned meats and vegetables prior to consumption, especially if they are home canned.

Ergotism and potato poisoning may be mentioned as rare forms of food poisoning. The first is caused by eating rye which is infected with the fungus ergot. Poisoning is sometimes caused by potatoes when they have grown too near the surface of the ground and show in consequence a greenish skin, or when old potatoes stored in a damp cellar have started to sprout.

Food Idiosyncrasy.

By food idiosyncrasy is meant the susceptibility of an individual to a certain food which is harmless to most people. Buckwheat flour, eggs, onions, oatmeal, milk, fruits, especially strawberries, and shell fish are the articles oftenest giving rise to this type of poisoning. In susceptible persons the symptoms come on a few minutes after eating and usually consist of hives and less often nausea or diarrhea. Specific food idiosyncrasy must not be confused with the belief held by many persons that some particular article of diet invariably gives them indigestion. Such statements are frequently based on a single experience of gastritis for the cause of which some article was blamed illogically and shunned thereafter.

There is a common but unfounded belief that some foods taken in combination "upset the stomach." In this belief many people refrain from eating lobster and milk at the same meal, but they enjoy without qualm the same ingredients in a more intimate mixture, such as lobster à la Newburg. Whatever poisoning occurs from a food combination is due to the putrefaction, infection, or indigestibility of one or both of the articles and not to an imaginary interaction.

Vomiting.

When irritating or poisonous material has been swallowed the protective reaction by vomiting may be induced. Vomiting is a complex series of movements of the respiratory and abdominal muscles and of the stomach itself following one another in a certain sequence and culminating in the expulsion of the stomach contents through the mouth. Vomiting starts with a deep inspiration, after which the windpipe is shut off by the glottis so as to hold the thorax rigid. The opening from the stomach to the intestines is then tightly closed, and that from the stomach to the esophagus relaxed. Spasmodic contractions of the abdominal muscles, the act of "retching," exert pressure against the stomach and force the contents out through the esophagus.

Vomiting may arise from other causes than irritation of the stomach. The whole act and its coördination are controlled by a special part or mechanism in the brain. This mechanism can be

stimulated reflexly from other organs than the stomach. Thus a blow in the abdomen, severe pain, tickling the back of the throat, or material lodging in the upper part of the windpipe may cause vomiting. Indeed, the mere thought, sight, or smell of disagreeable material may result in nausea and vomiting.

The act of vomiting is accompanied by changes in many bodily functions. The heart rate is slowed, the pressure of the blood in the arteries is lowered, and sweating, salivation, and muscular weakness follow.

Nervous Indigestion.

"Nervous indigestion," so called, probably is the commonest form of persistent gastric disturbance. The condition is characterized especially by discomfort after meals. This gastric distress consists of distention, eructation of gas, and "heartburn."

Nervous indigestion is not due primarily to any fault of the stomach, but rather to the conditions under which this organ is forced to function. Many of the circumstances of modern life are conducive to nervous indigestion; worry, nervousness, excitement, overwork, and the excessive use of alcohol, coffee, tea, and tobacco are the most common causes.

Nervous indigestion arises from disturbances in the coördination through the nervous system of the activities of the stomach. Many of the symptoms are due to the improper regulation of the valve which closes the passage from the esophagus to the stomach. This valve may become tense and open insufficiently to allow the passage of food into the stomach, so that both solids and liquids collect and distend the lower end of the esophagus, giving rise to a feeling of discomfort. On the other hand, the valve may relax unduly so that acid material from the stomach is regurgitated into the esophagus, thus giving rise to a stinging sensation known as "heartburn." This condition has no relation to the heart other than the general locality of the sensation to which the subject refers it.

During swallowing more or less air is carried with the food into the stomach and collects in the upper part near the esophageal opening. Passage of the gases as an eructation usually takes place with comparative ease. Nervous persons may eructate

habitually and quantities of gas many times the volume of the stomach may be raised in a comparatively short time. Severe and prolonged attacks of belching are usually associated with the swallowing of air, and if the person in whom they occur is watched closely it will be seen that swallowing movements regularly precede the eructation. The unconscious swallowing of air can be prevented and eructation stopped by holding the mouth slightly open by means of an object, such as a spool, placed between the teeth.

The acid gastric juice possesses strong antiseptic powers and kills most of the bacteria and other organisms carried in with the food, so that the material which passes to the intestines is usually sterile. Prior to its saturation with the acid secretion the growth of organisms continues. When material is retained in the stomach for an unusual length of time fermentation progresses energetically. Dilatation of the stomach is one cause for the retention of material in the stomach.

Capacity of the Stomach.

The normal capacity of the stomach when filled by a meal ranges from a few ounces in an infant to 1.5 to 2.0 quarts for an adult male, the female stomach being somewhat smaller. The habitual intake of unusually large amounts of solids or fluids into the stomach, as in heavy beer drinking, may lead to an increase in the size of the organ without causing what is technically called dilatation; the muscular strength is maintained and the stomach merely grows larger to accommodate a greater amount of material. Dilatation, on the contrary, is an overstretching and weakening of the muscles; there results a large and flabby stomach incapable of emptying itself completely. Dilatation sometimes results in a young person from overeating when the appetite exceeds the capacity or when the stomach is gorged in an eating contest.

Dilatation of the Stomach.

Gastric dilatation does not always have its origin in overeating; in fact, it occurs more often as a result of retarded emptying into the intestines and consequent accumulation and stagna-

tion of material in the stomach. Cancer or ulcer in the pylorus may lead to a partial occlusion of the valve, as may also less serious conditions such as the pressure from tightly laced clothing or from gastroptosis. Gastroptosis means fallen stomach and is a condition in which the fundus sags downward. The pyloric end of the stomach is firmly fixed in place by supporting ligaments. The gastric displacement results in a sharp angle at this attachment; the kinking delays the egress of food. Gastroptosis occurs much oftener in women than men. It is brought about by improper standing posture, weakened abdominal walls, or a state of general debility. The sufferers stand in a characteristic position, the head and shoulders stooped, the abdomen thrust forward, and the back bent to hold the balance. A similar slouching posture has been affected in recent years as a pose of fashion.

In gastric dilatation the stomach fails to empty completely and the contents therefore stagnate and ferment. The discomfort which the condition occasions depends on the degree of stagnation and results in a general weakened and nervous state. The term neurasthenia, which means lack of nervous strength, is often incorrectly applied to the effects which arise from gastric dilatation.

CHAPTER III

DIGESTION AND ITS DERANGEMENTS (*Continued*)

Small Intestine.

The small intestine is a thin-walled tube twenty to thirty feet in length, extending by a winding course from the stomach to the large intestine. The diameter of the intestine is determined by

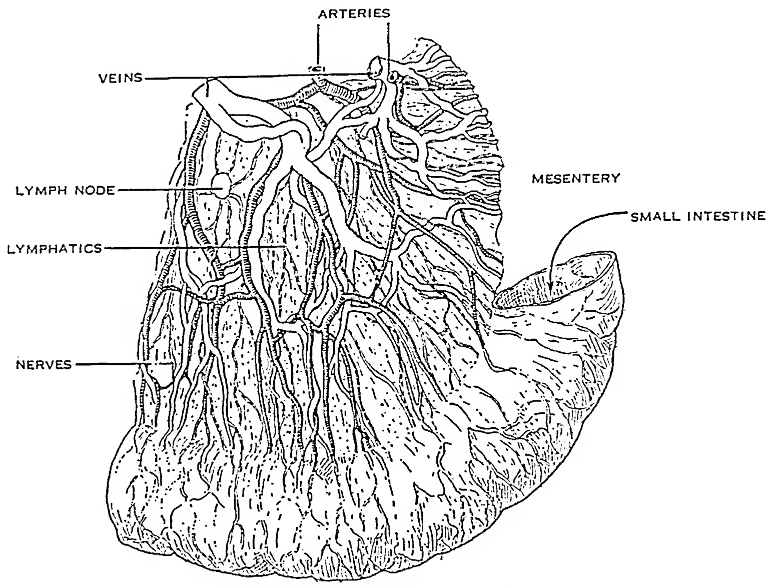

Figure 9. PORTION OF MESENTERY OF SMALL INTESTINE.

The mesentery, formed of a double layer of the peritoneum which surrounds the intestine, serves as a support for the blood vessels, nerves, and lymphatics supplied to the intestine.

the bulk of its contents; when well filled it is about an inch across at the stomach end and tapers slightly to its junction with the large intestine.

The intestine is covered with a layer of thin tissue called peritoneum. This layer does not extend completely around the periphery, but is reflected longitudinally in two closely placed layers which thus form a membrane called the mesentery, by which the

intestine is attached to the rear of the abdominal wall. The formation of the mesentery resembles a cloth sewed around a piece of pipe; the two edges of the cloth extending away from the seam are comparable to the mesentery. Its width from intestine to the body wall is about ten inches. At its line of attachment to the intestine, the mesentery has the same length as that organ (twenty to thirty feet), while at the attachment along the back of the abdominal wall the mesentery is only about a foot in length. Thus the mesentery presents two borders, one of which is twenty times as long as the other and, as would be the case with a piece of cloth, the mesentery is puckered or gathered. This puckering corresponds to the convoluted course which the small intestine follows. The mesentery serves both as an attachment to restrain the small intestines and as a support for the numerous blood-vessels and nerves which are supplied to this organ. The peritoneum which covers the intestines and forms the walls of the mesentery does not stop at the attachment along the back of the abdominal cavity; the two layers spread apart and follow around the walls forming a lining for the entire cavity. Inflammation of the peritoneum gives rise to the dangerous condition known as peritonitis; in medical terminology the suffix *itis* indicates inflammation.

Anatomically there are no lines of division in the small intestine, but it has been arbitrarily divided into three portions, duodenum, jejunum, and ileum. The duodenum consists of the first foot of the small intestine and is important in that the digestive fluids from the pancreas and liver are emptied there and mixed with the food.

Digestion in the Small Intestine.

Digestion in the small intestine is effected by ferments contained in the secretions from the pancreas and the glands of the intestinal walls, and is assisted by the bile from the liver. The gruel-like material from the stomach enters the duodenum and is there saturated with the alkaline secretion of the pancreas. The pancreatic juice digests starches, proteins, and fats. Its action upon the last of these foodstuffs is aided by the emulsifying properties of the bile. A secretion resembling that of the pancreas

is poured from small glands in the walls of the intestines. The secretion of the pancreas is delivered in a considerable quantity into the food material as it first enters the intestine; the intestinal secretions serve to keep it fully saturated throughout the entire passage.

The Pancreas.

The pancreas resembles a salivary gland. It lies along the lower side of the stomach in the space between that organ and the downward-curving duodenum. Besides manufacturing a digestive

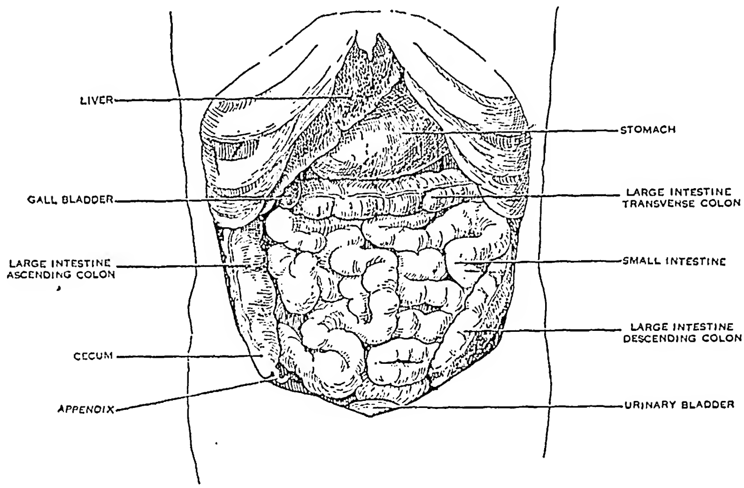

Figure 10. Abdominal Viscera.
The abdominal wall is removed to show the viscera in position.

secretion the pancreas has an important rôle in controlling the rate at which sugar is burned in the body. This metabolic function of the pancreas will be discussed in a later section dealing with diabetes (Chapter IV).

The Liver.

The liver is the largest gland in the body, weighing, in the normal adult, 1.5 to 2.0 kilos (3 to 4 pounds). It is situated in the upper part of the abdominal cavity, and is almost entirely covered by the lower ribs on the right side. The secretion of the liver, the bile, is a dark greenish fluid containing no ferments and is valuable to digestion only because of its emulsifying and solvent

action on fats. Unlike the secretion of other digestive fluids, bile is formed slowly and more or less continuously without reference to the presence of food in the intestine. The bile is collected in a small sac, the gall bladder, lying close against the under surface of the liver. From the gall bladder it is ejected as needed through a narrow duct leading to the duodenum. The amount of bile formed by the liver is very scanty for so large a gland. Besides, secreting bile the liver serves for the storage of sugar and for other functions also.

Gall Stones.

Although the digestive function of bile is of subordinate importance, nevertheless the secretion of bile is subject to more disturbance than is that of any other digestive fluid. Partial or complete obstruction of the duct leading from the gall bladder to the duodenum is the most common type of malfunction. There are two common causes of biliary obstruction—inflammation of the bile duct and gall stones. A catarrhal swelling at the opening of the bile duct into the duodenum is a common ailment, particularly in young persons; it may be occasioned by overeating or may result from infection, the so-called contagious jaundice. Gall stones are concretions resembling pebbles; they are made up of bile ingredients, and are formed in the gall bladder. So long as the stones remain in the bladder they occasion no disturbance, but their passage into the narrow bile duct leading to the duodenum is accompanied by severe pain and obstruction to the flow of bile. Stagnation of the bile due to incomplete emptying of the gall bladder is a factor in causing gall stones; so also is infection of the gall bladder. With advancing age the muscular tissue in the walls of the gall bladder becomes weakened and the bladder does not empty properly; in women the pressure from tight clothing or pregnancy tends to obstruct the flow.

Jaundice.

When the flow of bile is interrupted the digestion of fats becomes imperfect; in consequence the stools are colored dull gray and there is more or less diarrhea. Obstruction to the flow of bile does not, however, suppress its secretion. The gall bladder

becomes distended, bile under increased pressure is forced back into the liver and seeps into the blood stream. The bile in the circulating blood permeates all the tissues of the body, giving rise to the condition known as jaundice; the whites of the eyes, the skin, sweat, and urine all show the yellow color of the absorbed bile. The subject feels very unwell and despondent.

Obstruction of the passage from the gall bladder to the duodenum is the most common cause of jaundice, but jaundice occurs also in poisoning with phosphorus, with arsenurated hydrogen, from snake bite, and in certain infectious fevers, notably yellow fever.

Absorption in the Small Intestine.

The absorption of digested food material takes place almost entirely from the small intestine; very little in the stomach. Much water, but little else, is absorbed by the large intestine. The products of protein and carbohydrate digestion, amino acids and sugar, pass through the walls of the small intestine; they are then taken up by the blood stream, carried through the vessels of the mesentery, and brought to the liver. The products of the digestion of fats, glycerine and fatty acids, pass into the walls of the small intestine and are there combined into fat. Part of this fat passes into the blood and part into the lymph, a fluid which is held in a system of vessels distinct from those carrying the blood. The lymph with its burden of fat enters the blood stream without having passed through the liver. The subsequent utilization of the digested food materials is considered in Chapter IV.

Movements of the Small Intestine.

The movements of the small intestine mix the food which is being digested and pass it gradually along toward the large intestine. The intestinal wall constricts in closely spaced rings with relaxed areas between them; it thus divides the contents into small segments. The constrictions then relax, while the relaxed areas contract midway between the former constrictions; thus the small segments of material first formed are divided, and each half is united with a half of the segment on either side. This segmentation results in a thorough mixing of the food with the

digestive juices, and continually presents new surfaces of the material to the intestinal wall for absorption. At the same time the food mass is gradually passed along by the movements throughout the entire length of the small intestine. Such material as has not been absorbed during the passage passes into the large intestine.

Large Intestine.

The large intestine commences at the lower right quadrant of the abdomen; in its five and a half feet of length it ascends half-way up the right side of the abdomen, crosses to the left and descends; at the bottom it curves in an S or spiral-shaped bend, the sigmoid flexure, and so passes into the rectum. The first few inches of the large intestine make up the cecum, while the remainder, the colon, is further named according to its direction, the ascending, transverse, and descending colon. (See Figure 1.)

The small intestine empties through a valve into the side of the cecum. The portion below this entrance forms a blind pouch from which opens the vermiform appendix. The material leaving the small intestine is of fluid consistency; but during its passage through the large intestine most of the water is removed and the mass is reduced to a semi-solid state. The detritus which collects in the descending colon and rectum forms the feces which are evacuated by movement of the bowels. This fecal matter is made up only in part of indigestible material taken with the diet; it consists largely of dead bacteria from the large intestine, pieces of the inner coating of the intestine which have scaled off, and a very small amount of digestible food material which has escaped the action of the digestive juices or failed of absorption. Contrary to a common supposition, more than 95 per cent of all the digestible material in the food is absorbed by all healthy persons. The feces even when well formed, or even unusually hard, contain more water than solid matter.

Bacteria in the Large Intestine.

The material leaving the stomach is relatively free from bacteria, owing largely to the antiseptic properties of the gastric juice. The small intestine normally contains very few bacteria.

The bacterial growth in the large intestine, however, may be so extensive that dead bacteria constitute 50 per cent of the total weight of the dry fecal material.

Bacterial activities in the large intestine may play a part in digesting certain materials which are resistant to the action of the digestive juices of the small intestine. This is particularly the case in respect to cellulose, the woody fibers surrounding uncooked vegetable cells, for which there is no digestive enzyme secreted in the body. It is uncertain to what extent the products of bacterial action in the large intestine are used in the body.

The bacterial action in the large intestine normally causes no disturbance of health; it is a normal condition. When the diet contains proteins which are difficult to digest and which therefore reach the large intestine, the action of certain putrefactive bacteria on these proteins is attended with excessive gas formation. The flatulence which follows the eating of beans or other vegetables high in protein is produced in this manner. Cultures of bacteria, acidophilous, are sometimes taken, usually in milk, in order to establish the growth of a non-putrefactive strain of organisms in the large intestine.

It was formerly thought that the bacteria in the large intestine produced waste products which after their absorption, were detrimental to the general health. Much was said of so-called auto-intoxication. It is possible for such a condition to occur, but it is probably very rare. Interest has now turned from this imaginary auto-intoxication to focal infection and pus pockets about the teeth and tonsils. The headache and other effects of constipation are not due to absorption of injurious material from the large intestine.

Constipation.

Material normally passes through the small intestine in three to six hours and through the large intestine in about twenty hours. Most persons empty the material accumulated in the lower part of the large intestine and rectum once each day by defecation. Constipation is a condition in which the discharge of material is delayed for an unusual length of time. The usual cause for the delay is a retardation in the rate at which material is passed

through the intestines. Because of the relative amounts of time consumed in passage through the small and large intestine, the latter is chiefly responsible for constipation.

Causes of Constipation.

The greatest cause of constipation is improper diet. It is the presence of material in the intestines which stimulates the movement. During starvation the bowels may not move for weeks. An herbivorous animal will die of constipation if it is deprived of the bulky cellulose which normally excites the movement of its intestines; even carnivorous animals may suffer seriously from constipation, if fed solely upon such completely digestible materials as milk, eggs, and meat. The household dog and cat supplement their diet either with bones or vegetable materials to supply bulk for feces. Many persons live on a diet consisting exclusively of absorbable materials such as milk, eggs, meat, and sugar; and although their intestines are normal the stimulus to movement is lacking, and they suffer from constipation. By adding to their diet foods which are of a coarse and undigestible character their constipation is relieved. Bran has come into general use to furnish bulk to an otherwise highly digestible diet. Nothing is to be said against this article of diet except that recourse to it indicates meals insufficient in fruit and green vegetables which, in addition to furnishing bulk, supply needed mineral matter to the body.

A lack of water in the intestinal material may lead to constipation. The daily water intake of many persons, especially those of sedentary habits, is far below the normal minimum of six glasses a day; their intestines lack the fluid necessary to proper function. Although water should not be used to flush down partially masticated food, there is no harm, as is frequently and erroneously supposed, in taking liberal quantities of water during and immediately after meals. It is, in fact, desirable that water should be taken at such times. In warm weather and after exercise ample water is needed, for profuse sweating may lead to constipation through excessive absorption of water from the contents of the intestine.

The movements of the lower part of the large intestines which

initiate the act of defecation become fixed by habit, and most persons have a definite time of the day for evacuation. This regular habit is exceedingly important for the prevention of constipation. Change in the daily routine, with disturbance of the habit of regular evacuation during a train or boat trip, or during a vacation, frequently results in a period of constipation.

Constipation and Cathartics.

Constipation is due in some cases to a decreased excitability of the intestines so that they do not move to a normal extent when stimulated by bulky material. This type of constipation is generally caused by taking drugs for constipation. Laxative and cathartic substances—the difference is one of degree only—are divided into three classes: mineral oils, which simply lubricate the intestine and allow the food material to pass more readily; saline cathartics, such as magnesium sulphate and citrate, which cause a profuse flow of water into the intestines, give a wet and bulky mass and stimulate the intestines by this volume; and finally drug substances, which promote the excitability of the intestines either directly through chemical irritation of the walls or indirectly by their action on the nervous system. Habitual use of the drug type of cathartic leads eventually to chronic constipation. The intestines are at first excited to perform their movements energetically, but habituation decreases their excitability. Consequently, an increased amount of the drug must be taken in order to promote what should be a normal activity. Cathartics of the drug type should be taken only on rare occasions and when dietary measures have failed to relieve constipation. If we may judge from the money expended in advertising, America is a constipated nation. Unfortunately, many of the substances offered for general sale are habit-forming cathartics. The advertisements do not indicate the harmful nature, but dwell rather upon the character of the confection mixed with the drug. Repeated sales to the same persons and not occasional purchases pay for this advertising. Mineral oils and bran have brought less harmful elements into the field of cathartics. It would be still better to eat more of the green vegetables and fruits placed upon our tables.

Effects of Constipation.

Persons suffering from chronic constipation may have no ill feeling even though defecation occurs only at intervals of four or five days. In the condition of congenital dilation of the large intestine, fecal material may be retained for two weeks without marked discomfort. In the person whose habits are normal, constipation causes an uncomfortable feeling of fullness and distress, although health is rarely affected adversely unless the period of retention is very long. Although there is little evidence to support the belief, the idea that constipation is associated with the absorption of poisonous waste from the retained material is firmly rooted in the minds of most persons. A break in the normal habits of evacuation gives rise to nervousness. The feeling of well-being immediately after a satisfactory evacuation is due to the relief from pressure and the removal of nervous irritation and not to the sudden cessation of poisoning. The quickness of the relief is evidence that the effects are entirely mechanical; relief from "poisoning" would not occur at once when the absorption of the poison ceased but only after that which had been absorbed had been destroyed.

The mechanical and nervous irritations which arise from constipation affect the entire digestive tract. For purposes of description the digestive tract is divided into various portions, such as the stomach, intestines, and esophagus. From the aspect of function these divisions are artificial; the digestive tract operates as an entire structure. A disturbance in the function of any part affects the function of all the other parts. Inflammation of the appendix may cause both constipation and vomiting, although neither of these disturbances occurs in the appendix. Similarly, constipation, although arising from the lack of motility in the large intestine, nevertheless may affect the function of the remainder of the digestive tract. Constipation is primarily an indication, a symptom, that the intestines are moving sluggishly. The alimentary tract cannot perform its functions effectively unless the layer of muscle in the intestine is normally active. It is not the retention of material itself which is harmful, but rather the factors which cause the retention. Although constipation is not as serious as it is commonly believed, nevertheless it is an abnor-

mal state, a symptom of bodily derangement and of malfunction of the alimentary tract. Every effort should therefore be made to maintain regular habits of evacuation. The straining associated with constipation is an important factor in causing hemorrhoids or piles (Chapter VI).

Diarrhea.

Diarrhea is the term applied to unusually frequent passage from the bowels of material more or less fluid in character. Diarrhea results from an abnormally rapid passage of material through the intestines; the large intestine is not given sufficient time to extract the water. The increased motility may be caused by foods with a large undigestible residue, by chemical or mechanical irritation of the intestines, or by nervous and emotional disturbance.

Under the discussion of constipation it was stated that a diet insufficient in bulk failed to give the intestines the stimulus required to make them move; conversely, unusual bulk stimulates the intestines to a rapid passage of the material and diarrhea results. Fruits and uncooked vegetables taken in excessive amounts lead to this type of diarrhea. Unripe fruit and berries with rough seeds may cause diarrhea from mechanical irritation. Irritation by chemical substances is more common; it is caused by many drugs, poisons such as arsenic and antimony, spoiled food, and bacterial infection in the small intestine. Diarrhea of bacterial origin may be mild or of extreme severity, as in typhoid or Asiatic cholera.

The motility of the intestines is influenced by the emotional state; excitement or fear may give rise to the desire for defecation and may be followed by diarrhea. In some persons rapid movement of the intestines is associated with a rumbling sound and as mild an emotion as embarrassment increases the frequency of the sound.

Diarrhea involves a loss of water from the body and much of the prostration incident to prolonged diarrhea is due to this dehydration. Many persons use indiscriminately the words diarrhea and dysentery; the latter applies properly only to a severe form of diarrhea in which the stools contain blood.

Appendicitis.

The most important acute intestinal disorder is appendicitis or inflammation of the vermiform appendix. The appendix is a small tubular projection on the cecum, about the size of the little finger. The extremity is closed and the entire appendix resembles a slender test tube opening into the blind end of the cecum. In man this structure serves no function and is merely an evolutionary remnant from herbivorous ancestors. (See Figures 1 and 10.)

Appendicitis is generally a disease of young persons, 50 per cent of the cases occurring before the twentieth year. Appendicitis is caused by a local infection of the appendix, and usually with the bacteria normally found in the large intestine. The infection commonly follows an injury to the wall of the appendix such as an abrasion by fecal matter or a scratch from a body taken with the diet.

Acute appendicitis is characterized by pain and tenderness in the lower right side of the abdomen. Nausea and vomiting usually occur. The treatment of appendicitis is the surgical removal of the appendix. Delay in operation often results in a fatal outcome from the disease, for the inflammation increases, the appendix ruptures, and the infected intestinal contents pour out into the abdominal cavity, giving rise to peritonitis. Appendicitis was formerly a common cause of death and there are still many deaths owing to delay; for in the words of a famous surgeon, "There would be no deaths from appendicitis if every case commencing with acute pain, and developing tenderness and rigidity of the abdomen and quickening of the pulse, were operated upon within twelve hours."

Hernia or Rupture.

The protrusion of some organ of the body through the walls of the compartment in which it is normally contained is called hernia or rupture. Thus there can be hernia of the brain, when it bulges through an opening in a fractured or imperfectly formed skull; hernia of the liver into the chest cavity through a tear in the diaphragm, or hernia of the intestines with extrusion, when

a rupture has occurred in the muscles of the abdominal wall. The last type is far more frequent than any other.

The abdominal organs are contained in a cavity which makes up the greater part of the trunk of the body. This compartment is bounded above by the muscular diaphragm, which stretches across the body at the level of the lower ribs; at the bottom by the bones and muscles of the pelvis; behind by the spine and muscles of the back and laterally and in front by the muscular abdominal walls. In three places the wall of the abdomen is weak: at the umbilicus or navel; at the exit of the blood vessels which supply the legs; and around the spermatic cords of the male as they leave the abdomen to enter the scrotum. When hernia of the abdominal contents occurs, it is nearly always in one of these three localities, and is designated respectively as umbilical, femoral, or inguinal hernia.

In the male the testicles are developed in the abdominal cavity and remain there until a short time before birth. From this position they descend into the scrotum. In their descent they pass through the layers of muscle on the front of the abdomen. The openings made in the muscle are just above the bones of the pelvis which run across the base of the abdomen. The inner opening on each side is at some distance from the midline of the abdomen; the outer opening but a short distance from the midline. These openings are called the inguinal rings. In passing from the inner to the outer rings the testicles go between the layers of muscle, thus forming a passage known as the inguinal canal. As they descend, the testicles push ahead of them the peritoneum of the abdominal cavity; behind each of them extends the tube, the vas deferens or spermatic cord, through which their secretion passes.

The inguinal rings normally close tightly over the structures which extend through them, and the peritoneum is held thus firmly about the spermatic cords so that the intestines cannot extend along their course. In some cases, however, the peritoneum is not held firmly to the cords. In such cases the inguinal rings may become stretched as a result of the pressure of the intestines against them during muscular exertion, and a space is opened into which the intestines pass. The hernia thus formed may extend

no further than the cord or it may extend into the scrotum and distend it with loops of intestine.

Hernia may be recognized by the bulging of the abdominal wall over the point of extrusion. Gentle pressure usually serves to force the intestine back into its normal compartment; technically this procedure is called reducing the hernia, but on removing the pressure the hernia promptly recurs. In some hernias the extruded organ forms adhesions to the wall of the canal and becomes reducible only by operation.

There are three main causes of hernia: congenital imperfection of the abdominal wall, a weakened state of the abdominal muscles, and chronic strain. Hernia from chronic strains is common to men engaged in occupations which involve the repeated lifting of heavy objects. In lifting, particularly if the body is in the upright position, the abdominal muscles are strongly contracted; this increases the pressure within the abdominal cavity and tends to extrude the intestines. Hernia is more liable to occur as the result of repeated strain than from occasional muscular acts of exceptional violence; for the strain leads to a gradual stretching of the tendinous rings about the canals.

Untreated hernia in an adult is a severe physical handicap, for any strain may be followed by extrusion of the intestine. There are two treatments for hernia; a truss to hold the intestines in place, or an operation to decrease the size of the opening through which the intestines are extruded. A truss is a flat steel spring which encircles the body and bears on a pad placed over the hernia. The force of the spring is sufficient to counteract the extruding force exerted upon the intestines. A truss does not cure hernia in an adult; to hold the intestines in place it must be worn continually.

Strangulated Hernia.

The danger from hernia lies in the possibility that it may become "strangulated." A hernia is said to be strangulated when the extruded intestine is packed so tightly in the opening from the abdomen that its blood supply is shut off by the pressure. Strangulation commonly occurs as a result of the extrusion of an additional amount of intestine as the result of some sudden and violent

muscular effort. Strangulated hernia is a grave condition, for unless the blood supply is restored by operative reduction of the hernia within a very short time, the extruded intestine dies, gangrene or infection follows, and the outcome may be fatal. If the condition is recognized immediately, and the sufferer is quickly taken to a hospital and operated on before the part is dead, he may escape the otherwise serious consequences. The immediate course of events in strangulated hernia is usually quite characteristic: during some muscular effort a sharp pain is experienced at the locality of the hernia; this is accompanied by a feeling of faintness and a clammy perspiration. The period of shock is usually brief and is followed by vomiting, during which the abdominal pain increases in severity.

Animal Parasites of the Digestive Tract.

On both its outer and inner surfaces the body may be host to a variety of animal parasites; fleas may live and lice may thrive on the outer surface, while "worms" of various types may infest the intestine. Skin parasites make their presence known immediately, but a person may be unaware of the parasitic messmates which flourish within the body. Most intestinal "worms" give rise to no noticeable ill health, but a few give rise to unpleasant and even fatal effects, and one in particular, the hookworm, is responsible for the low vitality, stunted growth, and lack of efficiency in many millions of the inhabitants of warm climates.

Prevention of infection by the intestinal parasites can be effected only by knowledge of the manner in which they are acquired by human beings. The parasites have ingenious methods of propagation for their transfer to new hosts, without which they would rapidly die out. Most of them insure an exit for their offspring by allowing the eggs to pass out of the host's body with the feces. For some species of parasites the transmission is due entirely to the unsanitary habits of ignorant and slovenly people in disposing of their excreta, and to their lack of cleanliness in food and water supplies, thus allowing the eggs to reach the digestive tract of a new host. Infection with eel worms, whipworms, and ascaris can occur only through crude neglect of sanitation.

Tapeworm.

Tapeworms are carried in the flesh of animals consumed by man. Grass or other vegetables contaminated with human feces containing tapeworm eggs are eaten by hogs or cattle, and the eggs undergo partial development in the flesh of the intermediary animal host. When the flesh of an infected animal is eaten raw or imperfectly cooked the worms develop in the human intestine. The enormous chance of failure for any one egg involved in this method of propagation is partially compensated by the prodigious number of eggs produced by each adult parasite; for many years a tapeworm in a man's intestine will produce several thousand eggs each day.

Trichina.

The trichina worm is not primarily a parasite of man, but of rats; nevertheless entire human families are occasionally infected, and with serious consequences. The mode of propagation of the trichina is peculiar, and it is this mode of transfer which causes the painful and often fatal disease produced by the infection. The adult worm lives in the intestine of rats and produces young which, instead of passing out in the feces, burrow through the intestinal wall and into the tissues, where they become encapsulate in the muscles. When the rat is eaten by another rat, as is their habit, the young trichinæ are transferred to a new host. Hogs often feed on rats, or the infected offal of other hogs, and are thereby infected with trichinæ. Man acquires the worm from eating raw or undercooked pork. A few days after the infected material is eaten the disease trichinosis develops. Severe pain is caused by the worms burrowing through the muscles. The outcome varies with the degree of infection; the death rate ranges from 1 to 30 per cent. The disease is prevented by thoroughly cooking all pork products prior to consumption; this should be done invariably, even when the government has inspected the meat for trichinæ.

Hookworm.

The hookworm lives in the intestine attached to the wall by its characteristic hooks. It gets its nutrition from the blood which

it sucks from its host. Anemia, or lack of red coloring matter in the blood, is the outstanding feature of the disease which the worms induce. Children afflicted show a remarkable retardation of growth and are stunted; adults become emaciated. There is a disinclination for physical and mental exertion; the affliction is popularly spoken of as the "lazy disease." The expression of the face is dull and blank, the eyes vacant and staring. In some cases the disease is fatal, although this outcome does not seem to have a direct relation to the number of worms attached to the wall of the intestines.

The male hookworm is a quarter of an inch long and the female a quarter to a half inch. The mouth is provided with two pairs of sharp hooked teeth with which the worm grasps the intestinal wall. The eggs laid by the female are passed in the feces, and in a badly infected case the number at a single stool has been estimated as high as 4,000,000. In warm moist soil the eggs hatch in four or five days into larval worms, and in this state the parasite can persist in the surface earth for many months. From the soil the larval worm invades man by burrowing through the skin and occasionally by way of the mouth. The point of entry is usually through the skin of the feet, and the passage of the worm is followed by a local irritation which is called "ground itch." Once through the skin, the worms are carried in the blood of the veins to the heart and from there to the lungs, from which they burrow their way into the bronchi of the lungs. From the bronchial tubes the worms crawl up the windpipe and into the throat, are swallowed, and pass to the intestines, where they insert their teeth in the walls and are prepared to start over the whole cycle of propagation. A period of about seven weeks is covered from the time of entry until the eggs of the newly established worm are found in the feces.

The larval worms living in the soil cannot survive prolonged freezing, a fact which accounts for the geographical distribution and limitation of the disease. The area of infection belts the world in a zone about 66 degrees wide, extending approximately from 36 degrees S. to 30 degrees N. Some 940,000,000 persons live in this area. Surveys have been made to determine the extent to which the population of certain countries is infected with

hookworm; from 180,000,000 to 240,000,000 people are infected in India, 50 per cent of the total population of British Guiana, 50 per cent of the laboring population of Egypt; 70 to 76 per cent of the farming population of the southern two-thirds of China; and 70 per cent of the population of American Samoa. The southern portion of the United States is badly infected; estimates from different parts give percentages varying from 20 to 70.

Even in cold climates the hookworm may persist in mines and tunnels where the ground does not freeze. In such localities the soil pollution is unusually extensive, and the contact of the workers with the ground is intimate. A disease long called "miners' anemia" is now known to be hookworm disease. It is likely to develop in any subterranean work unless sanitary precautions are maintained.

The prevention of hookworm infection necessitates the disposal of fecal matter by sewage systems, deep burial, or chemical treatment, and especially the wearing of shoes. Although these sanitary measures are simple they are difficult to enforce on poor and uneducated people, stunted in mind and will by the parasites which their unsanitary habits foster. Of 61 patients with hookworm disease questioned in Porto Rico, 55 had never used a privy of any kind. Of 189,500 rural homes examined in the southeastern part of the United States, 96,000 were not provided with privies, 87,000 had unsanitary open back privies, and 6,500, or less than 4 per cent, had sanitary privies. In these same states some of the schools were provided with open privies which drained across the playground used by the barefoot children.

Hookworm disease is treated by expelling the worms from the intestines; a purgative is given first to clean out the digestive tract, this is followed by such drugs as thymol and carbon tetrachloride, which anesthetize the worms and cause them to relax their hold on the intestinal wall; a second purgative then flushes them out. Shoes must be worn out-of-doors at all times after the treatment; otherwise reinfection occurs. Persons who are cured of hookworm disease soon show a marked increase in industry, initiative, and energy.

Infections of the Digestive Tract.

The two most serious bacterial infections of the alimentary tract are typhoid and Asiatic cholera. In both of these diseases the specific bacteria enter the alimentary tract in the food and water. They infect the wall of the intestine and damage it. They are passed in great numbers in the fecal matter during the disease. Both typhoid and cholera are transmitted through the contamination of food and water with the fecal matter of those who have the disease.

Typhoid Fever.

The symptoms of typhoid fever appear within one or two weeks after the infection. As a rule they come on gradually; there is fever, the man feels ill, but there are no definite signs which characterize the disease at this stage. In the cases of so-called "walking typhoid" the disease is seriously advanced before the man is forced to his bed. Toward the end of the first week of the illness small red spots appear on the skin. Beyond these "rose spots" and some enlargement of the spleen there are no definite symptoms which characterize the disease as typhoid. Typhoid is, therefore, often mistaken for other diseases.

The bacteria primarily act upon the mucous membrane of the small intestine and cause ulcers and even a perforation of the wall of the intestine. They may also escape into the blood and infect other parts of the body. The symptoms arising from these secondary infections may obscure and render even more difficult the detection of the real nature of the disease. A positive diagnosis of typhoid can be made when a drop of blood from a man suspected of having the disease is brought in contact with typhoid bacilli under a microscope, the so-called Widal test. If the disease exists in the man from whom the blood was taken, the bacteria cease to move, but form in clumps; if the disease is not present the bacteria are unaffected. The mortality of typhoid is approximately 10 per cent. A quarter or more of the deaths result from perforation of the intestines.

The prevention of typhoid is a matter of education and sanitation. Food and water must be kept free from contamination

by the excreta of those who have the disease. Strict isolation of the typhoid patient, the sterilization of all excreta and bed linen, and careful screening against flies are the essential steps in prevention. It is difficult to carry out these measures. Carelessness and ignorance are contributing factors in the spread of the disease, but the chief difficulties lie in the inability to make an early diagnosis of typhoid, the presence of mild and incorrectly diagnosed cases of typhoid, and particularly because of the so-called "carriers." From 2 to 4 per cent of all persons who have had typhoid continue to pass typhoid bacilli in the urine or feces during and after the convalescence. In some of these cases the typhoid infection becomes chronic, usually in the gall bladder, and the bacilli are passed for years after all symptoms of the illness have disappeared. These "carriers," without themselves realizing the fact, spread the disease as would active cases of typhoid. There are typhoid carriers in every community; they spread the disease and necessitate general sanitary measures to safeguard food and water from contamination, or disinfection, if the contamination cannot be prevented.

Contaminated drinking water is a common source of infection. Most streams draining inhabited regions are contaminated with human feces. Surface water is, therefore, apt to contain typhoid bacilli. Attention has been directed so strongly to the epidemics arising from contaminated water supplies that most cities using surface water now treat the water with chlorine and thus destroy typhoid bacilli. In consequence water-borne infection has become a relatively minor cause of infection in cities. This type of infection still persists in small towns and in the country. Even well water may be contaminated by the drainage from a privy or cesspool. The appearance of water is not altered by contamination with typhoid bacilli. The clear, cool water of a mountain stream may be grossly contaminated by a typhoid carrier in a camp or dwelling some distance up the stream. The cases of typhoid contracted in the country during the summer vacation swell the total in the cities in the autumn. Surface water should either be boiled or treated with one of the various hypochlorite disinfectants before being drunk.

Typhoid infection is sometimes spread by milk. In such cases

the milk is contaminated either by a carrier who handles it or by the washing of the dairy utensils in water containing typhoid bacilli or by the dilution of the milk with such water. Pasteurization destroys the typhoid bacilli in milk. The best opinion is coming to be that all milk should be pasteurized.

An immunity to typhoid can be induced artificially by injecting dead typhoid bacilli beneath the skin. Usually three or four injections of increasing amount are made at intervals of five days. The immunity lasts for two or three years. Some reaction in the form of local inflammation or pain in the back and limbs occurs in about one-third of the cases inoculated, but it is not serious. The use of preventive inoculation practically abolished typhoid in the American army, even under the severe conditions of the European War. Preventive inoculation was not used during the Spanish War and one-fifth of the men in the national encampments had typhoid fever. During the South African War the British army lost 7,582 men as a result of wounds received in battle and 8,225 from typhoid.

Cholera.

Any severe disturbance of the alimentary tract associated with diarrhea and cramps is called cholera. The food poisoning described in a previous section may be of sufficient severity to be included in this classification. Cholera of this type is particularly prevalent in warm weather and for that reason is often called "summer complaint." A similar but much more fatal type occurs in young children and is known as "cholera infantum." The infection in these cases is not limited to one particular type of bacterium, but may be caused by any one of many types. Asiatic cholera, the most serious type of cholera and one of the most deadly of all diseases, is, however, caused by a specific type of bacterium.

Asiatic cholera has been endemic in India from a remote period, occasionally spreading over that country in epidemics which have taken a frightful toll of lives. Within the last century the disease spread to Europe and America. In 1832 Asiatic cholera was brought to Quebec in emigrant ships from Great Britain. From there the disease followed the lines of traffic up the Great

Lakes and reached as far west as the military posts of the upper Mississippi. In the same year it also appeared in New York. In 1848 it entered the country through New Orleans and spread up the Mississippi Valley and across the continent to California. Six years later it was again introduced in emigrant ships and spread throughout the country. It appeared last in the United States in 1873. Although since then, particularly in 1907-11, wide epidemics have prevailed in the Near and Far East, the quarantine of immigrants has prevented the entrance of the disease into this country.

Asiatic cholera is caused by an organism which from its shape is known as the comma bacillus. The mode of transmission and prevention is the same as that for typhoid fever. Moreover, as in the latter disease, there may be "carriers." Asiatic cholera is a much more fatal disease than typhoid; the mortality ranges from 30 to 80 per cent.

A period of two to five days elapses between the infection and the onset of the disease. The symptoms are those of violent diarrhea with vomiting and great weakness. So extensive is the loss of water through the incessant diarrhea and vomiting that the blood volume and tissue fluids are dangerously depleted. The thirst is intense. Within a short time the features are shrunken, the cheeks hollow, the eyeballs sunken, and the skin shriveled. Treatment by the injection of dilute salt solution into a vein has materially reduced the mortality of the disease in recent epidemics.

Amebic Dysentery.

The ameba is the most elementary of animals; it consists of a single cell, a minute irregular bit of protoplasm. Amebæ are commonly found in the water of stagnant pools and are usually harmless when ingested. One type, known as ameba dysenteriæ, when taken into the body in the food or water, attacks the walls of the intestines and produces ulcers. In consequence diarrhea and dysentery follow. The disease may be acute and result in death, but more often it is of a chronic nature, lasting for years. These chronic cases have periods of dysentery followed by improvement, and then a recurrence of the dysentery. The sufferers usually lose weight and may even become emaciated. The

amebæ sometimes penetrate the walls of the intestine and find their way into the liver, where they form abscesses. The cure of amebic dysentery is often difficult, particularly in the chronic form of the disease.

Amebic dysentery is widely prevalent in Egypt, in India, and in tropical countries. It also occurs in the southern part of the United States. The amebæ pass from the body in the fecal matter and the disease is transmitted by the contamination of food and water, as in the case of typhoid and cholera.

CHAPTER IV

FOOD, WORK, AND HEAT

Fate of Foods in the Body.

The transformations which the food undergoes after being absorbed into the body are called metabolism. Metabolism may be studied from the aspect of energy liberation and estimated for any period from the work and heat produced by the body. Or it may be studied by following the changes which a particular food undergoes from the time it is absorbed into the blood until it is eliminated as waste; thus we speak of the metabolism of fats, proteins, and carbohydrates.

Metabolism of Carbohydrates.

The maintenance of a nearly uniform concentration of sugar (glucose) in the circulating blood is one of the fundamental adjustments of the body. In spite of great fluctuations in the consumption of carbohydrates, the blood leaving the heart contains, within narrow limits, 0.1 per cent of sugar. This uniform concentration is maintained by means of a system of storage and mobilization safeguarded by an emergency overflow.

The simple sugars, chiefly glucose, formed as end products of carbohydrate digestion, are absorbed into the blood in the vessels surrounding the intestines. All of these vessels converge into a common channel, the portal vein, which goes to the liver. This organ abstracts from the blood reaching it any sugar in excess of the normal 0.1 per cent and converts it into a kind of starch, called glycogen, which is stored in the liver. Whenever the blood passing through the liver contains less than the normal amount of sugar, glycogen is reconverted into sugar, and the deficit is made up.

The human liver has the capacity to store 150 to 250 grams (6 to 9 ounces) of sugar. It is thus able to arrest and fix any ordinary amount coming from the digestive tract. The intake of a large amount of readily assimilable carbohydrate, such as a

pound of candy, floods the sugar-storage capacity of the liver and the concentration in the blood rises above the normal. The kidneys then act to restore the normal concentration. Blood containing 0.1 per cent of sugar passes through the kidneys without appreciable loss of sugar; but if the content is higher, the excess of sugar is excreted into the urine. This overflow of sugar into the urine as a result of excessive ingestion does not often occur; for the forcing of such an excess of readily assimilable carbohydrate is nauseating to most persons.

The muscles as well as the liver store sugar as glycogen, but the capacity for storage of sugar in this form is limited. There is another mode of storage which is of unlimited capacity. Carbohydrates can be converted into fat and stored in that form; the fact that sugar and starches are fattening is a commonplace. The fat deposited in the body is drawn on for fuel whenever the food intake falls below the energy expenditure.

The rate at which sugar is mobilized from the glycogen in the liver is not entirely automatic, but is influenced to some extent by emotional states. Fear, rage, and pain cause an increase in the concentration of sugar in the blood, presumably that there may be a supply of this fuel ready for the expected muscular exertion of flight or combat. When the exertion does occur, the extra sugar is burned, but if the emotion is suffered without exertion some of the excess sugar may pass into the urine. Sugar can frequently be found in the urine of football substitutes anxiously waiting on the side lines; but it is never found in the urine of the active players.

The combustion of sugar in the body to form carbon dioxide involves chemical reactions in which lactic acid is formed as an intermediate step. It suffices for our purpose here to express the process in its initial and final stages only:

$$\underset{\text{(glucose)}}{C_6H_{12}O_6} + 6O_2 = 6H_2O + 6CO_2 + 4.1 \text{ kilocalories}$$

In burning a single molecule of glucose, six molecules of oxygen are used, and six of carbon dioxide are liberated. If sugar were the only fuel burned in the body the amount of oxygen consumed and the amount of carbon dioxide produced would be

equal. As will be seen in the section on energetics, this ratio, the "respiratory quotient," indicates the type of fuel burned in the body at any time.

Sugar is constantly being burned in the body so long as there is a considerable supply of glycogen. When the glycogen becomes reduced, as it does during fasting, fat is burned instead of sugar, although the blood still contains sugar. Under these circumstances some fat may even be converted to sugar. Muscular exertion performed during fasting still burns some sugar and reduces further the store of glycogen. When the store of glycogen is exhausted muscular exertion becomes difficult and severe exertion is impossible; a Marathon runner collapses when he has consumed all of his glycogen and all of the sugar in his blood.

Diabetes.

In the disease called diabetes the combustion of carbohydrates is deranged. In the common form of this malady the primary disturbance is in the pancreas. The function of this gland in secreting a digestive fluid has already been considered. It has also a second and even more important secretion which does not pass into the digestive tract, but into the blood. This internal secretion exerts a chemical control over the combustion of sugar. The combustion of sugar in the body cannot take place normally when this secretion is lacking. The carbohydrates of the food, although properly digested and absorbed, are not then utilized for fuel, but accumulate in the blood and finally pass into the urine. Aside from the waste of fuel involved, the high concentration of sugar in the blood exerts an unfavorable influence upon bodily health; in particular it reduces the resistance to bacterial infection. Even in normal persons a diet high in carbohydrate, particularly sugar, predisposes to boils and pimples. Diabetes results in loss of weight and muscular strength. Oxidation of fats as well as sugar may be interfered with as the disease becomes more severe. Death results unless active measures are taken to combat the condition. In many cases of diabetes of moderate severity, a diet entirely free from carbohydrates relieves the symptoms of the disease; with improvement a small amount of starch or sugar may finally be tolerated and utilized. One of the chief predis-

posing conditions for diabetes is obesity. Life insurance companies charge higher rates to persons who are overweight. An increase in weight above the normal may be considered as one of the first symptoms of diabetes.

Insulin.

The internal secretion of the pancreas, called "insulin," is now extracted from the pancreatic glands of slaughtered animals and sold for medical purposes. Injection of insulin into the blood of a man suffering from diabetes is followed by a temporary return of normal sugar combustion. Insulin does not in the strict sense cure diabetes. So long as injections are given the carbohydrate metabolism remains normal and the health and strength are restored correspondingly. If the initial deficiency of the pancreas is amenable to improvement the relief given by insulin affords an opportunity for recovery. After stopping the insulin treatment the diabetic may, in mild cases, be kept in health by means of a diet low in carbohydrates; if this measure is not effective the insulin must be continued indefinitely.

Metabolism of Fats.

The supply of sugar in the body determines the extent to which fat is used as fuel. If there is a surfeit of sugar beyond the storage capacity, sugar alone is burned until the excess is utilized; as the supply of sugar and glycogen is consumed a greater proportion of fat is burned. Under ordinary conditions there is always sufficient fat to supply the tissues with fuel, for the amount of fat stored in the body is large. An abundance of fat in the blood, such as occurs after a meal rich in this substance, does not increase the proportion of fat burned, as would be the case with sugar. Fat is a less efficient fuel for muscular work than is sugar; muscular efficiency is less, more heat is produced for the same exertion, more oxygen is used, and the fatigue is greater (see Chapter XIX).

The storage and mobilization of fat in the body are not so precisely controlled as in the case of sugar. After meals containing fat the blood may contain an increased amount of fat in the form of globules, an emulsion like milk. If such blood is drawn

from the body and allowed to stand fat separates and floats on top, as does the cream on milk. The excess of fat in the blood is gradually accumulated in depots about the body and this process may continue up to extreme obesity. On the other hand, when the amount of fat absorbed from the digestive system is insufficient to balance the need for fuel the fat previously deposited reënters the blood. If this deposit and withdrawal of fat is not exactly compensated by the diet over any period there is gain or loss of weight. (Considerable fluctuations in the weight occurring during a single day are due to variations in the water content of the body; they may amount to three or four pounds or even more.)

Except in the most extreme emaciation there are deposits of fat about the abdominal organs and beneath the skin. In the latter locality it serves as an insulating layer and conserves the heat of the body. If the subcutaneous layer of fat is consumed the contour of the body becomes sharp and angular, for it is this layer of fat which imparts graceful curves to the figure. The areas of major deposition differ somewhat in men and women; in men the abdominal wall is the especial site, while in women the fat is more evenly distributed, and particularly over the hips and shoulders. The fact that women need less clothing over their arms and shoulders than men has thus a physiological basis.

The combustion of fat takes place in several steps, of which the initial and final stages are given in the following equation:

$$\underset{\text{(Fat)}}{2C_{53}H_{98}O_6} + 149O_2 = 98H_2O + 106CO_2 + 9 \text{ kilocalories}$$

Both water and carbon dioxide are formed; 70 per cent of the oxygen used goes to form the latter. The volume of carbon dioxide produced in burning fat is only 0.7 as great as the volume of oxygen used; the respiratory quotient is therefore 0.7.

Metabolism of Proteins.

Proteins are split into amino acids in the course of digestion (see Chapter I) and are absorbed into the blood in this form. A part of the amino acids is used to build human protein for the growth and repair of the body. Any in excess over this need is burned as fuel or converted into sugar. Amino acids contain nitrogen which cannot be burned in the body. This nitrogen is

separated in the form of urea and in the separation carries with it part of the hydrogen and carbon of the amino acid. Urea is eliminated through the urine. As urea contains unburned carbon and hydrogen, protein gives less heat when consumed in the body than when burned in a calorimeter; 4.1 kilocalories from one gram in the body and 5.6 in the complete combustion of all the carbon and hydrogen in a calorimeter.

Need for Protein.

Except in men eating meat exclusively, protein is vastly more important as material to maintain the body than as a fuel food. The breaking down of the protoplasm of the cells of the tissues is continuous, and if the waste is not made good by the ingestion of protein the body ceases to function efficiently. Protein starvation is characterized by lassitude and increased susceptibility to fatigue.

All proteins contain within narrow limits the same amount of nitrogen, about 16 per cent. The amount of nitrogen as urea found in the urine is, therefore, an index of the amount of protein broken down in the body. This nitrogen does not necessarily come from protein which has been recently eaten, for the protoplasm of the body lost in the daily wear and tear is burned in exactly the same manner as any other protein. When the diet is adequate in fats and carbohydrates, but lacking in protein, urea continues to be excreted in the urine, and this nitrogen is derived solely from the disintegrated protein of the body. By estimating each day the amount of nitrogen in the urine during a period of protein starvation, it has been found that the disintegration of the body progresses at a uniform rate. This type of experiment indicates the approximate amount of protein required for the maintenance of the body—that is, the amount of protein which must be eaten daily to replace that which the body has lost.

In an adult on a normal diet the amount of nitrogen as urea in the urine for any considerable period, exactly equals that contained in the protein which is eaten. This relation of nitrogen balance signifies that the daily intake of protein is adequate or more than adequate for the needs of the body. If the intake of

protein were less than the need for protein there would be at first a greater nitrogen excretion than intake. Eventually, however, the amount in the urine would diminish, but health would suffer. Less nitrogen in the urine than in the food signifies a retention of protein in the body. This condition occurs in growing children, during convalescence after a wasting disease, and as a concomitant of the increase in size of muscles which follows exercise. The ordinary activities of life have only a slight influence upon the rate at which protoplasm breaks down; not much more meat is needed after a day of violent exertion than after one spent quietly.

The minimum of protein required daily by an adult cannot be established exactly. It is in this respect comparable to the income of money by which a man supports himself; below a certain income the man continues to live, but he lives poorly; above a certain income he lives well. An adult receiving 50 grams of protein each day has an adequate amount; a greater amount does him no more benefit; a considerable reduction below this amount would eventually lead to ill health. The effects of an insufficient amount of protein in the diet are sometimes observed in children as a result of the low protein ration of war time. These children develop hunger edema or dropsy; the abdomen becomes distended with fluid.

Most persons on a free choice of diet consume about three times as much protein as they actually need. Meat is the main source of protein, but 50 grams of meat does not supply 50 grams of protein; beefsteak, for example, contains water, fat, and other substances in addition to protein. In order to obtain 50 grams of protein from this source alone it would be necessary to eat some 200 grams of beefsteak (approximately half a pound).

Protein and the Kidneys.

Since most persons eat much more protein than the body absolutely requires, the kidneys must do more than the minimum of work by reason of the extra urea elimination through them. A reduction in the intake of protein is often recommended on hygienic grounds and the policy is carried to fanatical extremes by many persons. In such cases it is meat that is limited; but this

limitation is not always logical. Proteins from some vegetable sources do not contain all the amino acids in the right proportion to manufacture human protoplasms or certain amino acids may be entirely lacking. It is necessary to eat a comparatively large amount of some kinds of protein in order that the body may receive a sufficient amount of one amino acid to replace the daily loss; the amino acids which are present in excess are broken down and the urea passes through the kidneys. The following table gives the amounts of various common proteins required to supply 50 grams of human protein:

Meat protein 50 grams
Milk protein 51 grams
Rice protein 57 grams
Potato protein 57 grams
Bean protein 63 grams
Bread protein 127 grams
Indian corn protein 170 grams.

Although bread is a good fuel it is, as indicated in this table, a poor source of protein for the repair of the human machine. Bread contains 9.5 per cent of protein, and in order to obtain from this source alone the 127 grams necessary to replace 50 grams of human protein, it would be necessary to eat 3½ pounds of bread each day, or more than a loaf at each meal. At the same time the kidneys would be called upon to eliminate from the 127 grams of protein 2½ times as much nitrogen as they would if the necessary minimum of protein were supplied in the form of meat. It is not probable that a diet high in protein harms the normal kidneys. These organs in this respect react in the same manner as the normal heart does to exercise—they hypertrophy, that is enlarge. Excessive protein may be harmful to the diseased or weakened kidney just as exercise may be harmful to the diseased or weakened heart.

Uric Acid and Gout.

A small amount of the nitrogen split off from meat protein takes the form of uric acid instead of urea. Certain materials give especially large amounts of uric acid, such as liver, sweet-

breads and the roe from shad or other fish. Uric acid is also formed from what is known as meat extractives; these are the substances present to some extent in all meats, but particularly in those which form such soups and bouillons as beef tea. Uric acid manufactured in the body is converted into the sodium salt which is a very slightly soluble substance. Disturbance in the elimination of uric acid and an excessive formation of sodium urate give rise to the disease gout. The excess of sodium urate in the blood is deposited about the joints, and particularly the joint of the great toe. The fundamental cause of gout is not known; an hereditary tendency is evident, while the predisposing factors are sedentary habits, overeating, and indulgence in rich wines. Chronic poisoning by lead may also be a factor in causing gout.

Rate of Energy Expenditure and Its Measurement.

The rate at which foods are burned is determined by the momentary need of the body for energy. The combustion of fuel and the liberation of energy as both work and heat take place simultaneously, much as in an internal-combustion engine; indeed, some of the combustion follows the work. In this the body differs from a steam engine where the heat is produced first and the work liberated afterward.

There are three main methods of determining the rate at which human energy is expended: 1. By direct measurements of the heat eliminated from the body's surface. 2. By calculation from the rate at which oxygen is consumed and carbon dioxide produced by the body. 3. By the calorific value of the diet. Each of these three methods has its own special advantages. The first can be made very exact and gives an energy value directly, but requires elaborate apparatus. The second requires less apparatus and is more flexible in application; with this method a man's expenditure for as brief a time as one minute can be determined. The third is applicable not only to a single person, but even more easily to a group of people or to a whole nation, but it is accurate only when taken over a fairly long period of time. In the war whole nations were rationed on the basis of just enough food to supply the necessary vital fuel.

Direct Calorimetry.

In the method of direct measurement, the subject is placed in the chamber of a calorimeter and the heat liberated by the body is determined over a period of an hour, a day, or even longer. Provision is made to measure the mechanical energy of any work performed by means of an ergometer. The essential part of the calorimeter is an adiabatic room, a box within a box, from which the heat loss or gain by conduction to the outside is prevented by maintaining the outer walls at exactly the same temperature as the inner by means of delicate electrical controls. A measured stream of water passes through the chamber in a coiled pipe and the difference in the temperature of the water at entry and exit gives the heat removed from the calorimeter. The results obtained by this elaborate method of direct calorimetry have proved that the principle of the conservation of energy holds true in living beings, and have demonstrated the theoretical correctness of the simpler method of indirect calorimetry.

Indirect Calorimetry.

In indirect calorimetry the energy developed in the body both as work and heat is estimated from the amount of oxygen consumed. The combustion of carbohydrates and of fats follows definite chemical reactions (see pages 60 and 63). A gram of carbohydrate on combustion in the body liberates 4.1 kilocalories of energy and in the reaction 0.8 liter of oxygen are consumed. A gram of fat on combustion yields 9 kilocalories of energy, and 2 liters of oxygen are consumed. The oxygen to supply these chemical reactions is taken from the air inhaled into the lungs; the carbon dioxide produced is passed out in the expired air. By determining the rate at which oxygen is consumed and carbon dioxide is produced by the body, the rate at which energy is liberated can be calculated.

The man on whom the determination is made breathes through a mouthpiece. The air current is directed by check valves so that atmospheric air is inhaled, but the expired air is passed into a large rubber bag or a gasometer. After the desired length of time the volume of the expired air is measured and the percentage

of oxygen and carbon dioxide which it contains are determined by analysis. From these values the man's consumption of oxygen and production of carbon dioxide are calculated. The relation of the volume of oxygen consumed to that of the carbon dioxide produced, the respiratory quotient, indicates the proportion of fat and carbohydrate used as fuel (see pages 61 and 63). The values obtained afford the data necessary for the calculation of the rate of energy expenditure during the time of the experiment.

For certain types of routine work, as in hospitals, a simplification is made in the procedure of indirect calorimetry by assuming a normal respiratory quotient of 0.8. Instead of collecting the expired air the subject is made to breathe back and forth from a small gasometer filled with oxygen or air enriched with oxygen. The carbon dioxide of the expired air is removed by a cartridge of alkali placed in the circuit. The decrease in the volume of oxygen in the gasometer is read directly as the oxygen consumption over the period of rebreathing. This volume multiplied by the heat equivalent for oxygen at the assumed respiratory quotient (4.8 kilocalories per liter) gives the energy expenditure for the period.

Dietary Calorimetry.

In a state of equilibrium the energy output of the body equals the total calorific value of the diet. The equilibrium of income and outgo ceases if the body gains or loses any considerable weight which would indicate a gain or loss of fat and hence a diet which is not in equilibrium with the energy needs. The dietary method is used to approximate the total energy expenditure of a group of people. The heat value of the food purchased by an army cantonment minus that in the table scrap is the energy expended by the men fed; the calorific value of the food raised by a nation plus the imports and minus the exports is the energy expended by the people of the nation.

The principle underlying the dietary method of calorimetry has a corollary: in order to maintain the body in a normal state the diet must have a calorific value equal to the energy expended (see Chapter V).

Basal Metabolism.

The rate at which energy is expended by any individual is subject to wide fluctuations according to the muscular activity of the body. The relative expenditure of different individuals under identical conditions of activity depends upon age, size, and muscular efficiency. The amount of energy expended by the body is at a minimum in an individual lying in bed before breakfast (it is somewhat lower during sleep). This minimum rate of energy expenditure is called the basal metabolism. Determination

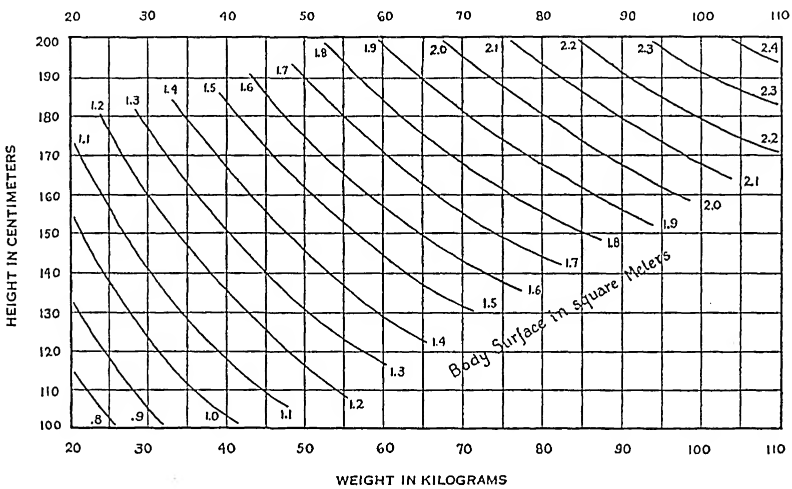

Figure 11. Area of the Body Surface from Weight and Height.

The curve (or interpolated curve) touched by the intersection of a line extending from the subject's weight on the abscissa with a line extending from the subject's height on the ordinate gives the area of the subject's body in square meters.

of an individual's basal metabolism gives nearly the same value day after day. The value found is an essential constant of his body. The energy output is that required to maintain the necessary and never-ceasing operations of the body; to circulate the blood, to keep the body at a normal temperature, and to hold the muscles in that state of slight tension or tonus which differentiates the living flesh from the flabby nonresistant state which follows death.

In general the basal metabolism increases with the body weight, but the increase is not proportionate. It is the surface area of the body which determines the value of the basal metabolism; all

normal adults in the basal state have the same heat loss per square meter of the body surface within ± 10 per cent. The average normal is 39.7 kilocalories per square meter per hour.

It is very difficult to measure directly the area of the surface of the body. This function varies with the weight and height so that a close approximation can be made from these values, which are readily obtained. A diagram from which the area is obtained is shown in Figure 11.

Energy Expenditure and Mental Activity.

The amount of the basal metabolism falls progressively from birth to old age. The variations with age correspond to the general changes in the growth and activities of the tissues of the body. The metabolism taken during sleep is some 15 per cent lower than the basal; the difference is due to the relative degree of alertness and tension of the muscles.

The question is frequently asked whether mental activity has a measurable influence upon the basal metabolism. Nervous tissue takes oxygen from the blood and returns carbon dioxide, and therefore presumably liberates energy. Nevertheless, all attempts to demonstrate an augmented energy expenditure during mental activity have given indefinite results. The nerves and brain make up only about 4 per cent of the weight of the body, so that even a marked change in the energy liberation of this portion of the body would be unrecognizable in a measurement made upon the body as a whole. Nervous activity involves energy expenditure and oxidation, but in extremely small amounts.

Increase in Metabolism Due to Taking Food.

After eating protein material the basal metabolism is increased by 10 to 30 per cent; carbohydrates have less influence in this respect than proteins, that of fats is negligible. If the body is at rest the extra heat generated as a result of eating protein or carbohydrate is wasted; meat and, to a less degree, sugar are therefore "heating" for the person of sedentary habits. If work is done, however, the extra energy can be utilized in that form, so that no greater heat production accompanies work done after than before meals.

The increase in metabolism which follows the taking of food is not to be thought of as similar to the increased heat production in a steam boiler on addition of fuel to the fire. The activity of the cells throughout the body, and particularly in the liver, is probably excited by the syntheses and readjustments which take place in the digested protein leaving the alimentary canal.

Metabolism and Body Temperature.

A uniform temperature is one of the essential constants of the body; this temperature is maintained by the heat liberated during the combustion of food. The body is equipped with an efficient regulating mechanism by means of which the heat loss is controlled; but it can be only partially prevented (see Chapter XX). In warm climates the heat developed by the metabolism during the quiet state is sufficient, or more than sufficient, to make up the minimum heat loss, and temperature regulation is then entirely a matter of the dissipation of any excess of heat produced. In cold climates housing, cloth, and artificial heat produce conditions which, so far as the body is concerned, are equivalent to a warm climate. Since these artificial conditions can be varied to suit the comfort, heat regulation is carried out for the most part by the same mechanism in both hot and cold climates. When the housing, clothing, and artificial heat are insufficient to duplicate for the body a semi-tropical climate, the heat production during the resting state becomes insufficient to support the normal body temperature. The additional heat needed may then be obtained by exercise. If this is not resorted to, the so-called "chemical regulation of temperature" is called into play to increase the rate of metabolism. This chemical regulation is in reality involuntary exercise. The muscles are first more tense; they even feel stiff. This static effort involves heat production. If the increased tonus does not furnish sufficient heat the muscles twitch rapidly—the condition called shivering.

Muscular Exertion and Rate of Metabolism.

Muscular work influences the metabolism to a greater extent than does any other condition; the increase of metabolism is proportional to the muscular exertion. The term muscular exertion

is used here in a somewhat broader sense than that of physical work alone, for energy is expended during many muscular efforts in which no physical work is performed. For example, when a man lifts a weight he performs a muscular exertion, expends energy, and does work; when he holds the weight at arm's length he also makes a muscular exertion and expends energy, although he does no physical work.

The amount of physical work which is performed by the man in lifting the weight equals the product of the mass of the weight times the distance through which he raises it. In order to accomplish this work his body expends energy; food is burned and its chemical energy liberated, partly as manual work and partly as heat which is dissipated from the body. The total chemical energy liberated is the heat equivalent of the amount of material burned in the tissues; and this exactly equals the heat produced plus the thermal equivalent of the work performed. The proportion of the total energy which appears as work is an expression of the efficiency of the muscle which performs the task. The total thermal efficiency of the muscles ranges from 15 to 35 per cent.

The energy expended in performing any particular work is not the total energy expended by the body during the time in which it is performed; the total is the sum of the energy spent in maintaining the body at rest plus that expended in doing the work. For example, a man while sitting still expends energy as heat at the rate of 100 kilocalories (390 B.T.U.) per hour; he then turns a grindstone by means of a foot treadle, thus doing work at the rate of 14,167 kilogram meters (101,290 foot pounds) per hour. This amount of work in terms of heat is 33.3 kilocalories (130 B.T.U.). Assuming that the total thermal efficiency of the muscles performing the work is one-third, twice as much energy is dissipated from the body in the form of heat as is expended as physical work. The energy cost to the man turning the grindstone for one hour is therefore not 33.3, but 100 kilocalories. This amount added to the expenditure during a similar period of the resting state gives the approximate total energy expended during the hour in which the task was performed. This total is 200 kilocalories. (780 B.T.U.).

The amount of food which is required to provide the energy

for this expenditure can be calculated readily from the heat value of the foods. The necessary 200 kilocalories would be furnished by approximately 40 grams (1.5 ounces) of sugar or 19 grams (0.7 of an ounce) of fat; 1 gram of carbohydrate yields 4.1 kilocalories, and 1 gram of fat 9 kilocalories. As will be seen later, one and one-half glasses of milk or two eggs would also supply this amount of energy. If instead of turning the grindstone the man had remained at rest in his chair, his energy expenditure and food requirements, under the circumstances chosen here, would have been one-half as great as they were during the exercise.

The basal metabolism and that during sleep are the lowest rates at which energy can be expended; the highest is that of a man performing the maximum amount of work of which he is capable for even a short period, and may run up to forty times the basal, but the maximum for any length of time, as in a boat race or Marathon race is ten to twelve times the basal.

The following table gives the energy used per hour in various occupations; the values are necessarily merely rough averages:

TABLE I

TOTAL ENERGY EXPENDITURE PER HOUR OF A MAN OF AVERAGE SIZE, 70 KILOS (154 LBS.) UNDER DIFFERENT CONDITIONS OF ACTIVITY

	Kilocalories per hr.	B.T.U. per hr.
Sleeping	60–70	235–275
Awake, lying still	70–85	275–310
Sitting at rest	100	390
Standing at rest	115	450
Typewriting	140	550
Walking two and one-half miles per hour	200	780
Carpentry, Painting	240	935
Walking three and one-half miles per hour	300	1170
Sawing wood	450	1755
Running five and one-quarter miles per hour	500	1950

The daily energy expenditure and food requirements for a person of average size can be approximated from the values given in the table above. For example:

8 hours of sleep at	65 calories	=	520 kilocalories
2 hours walking at	200 "	=	400 "
8 hours typewriting at	140 "	=	1120 "
6 hours sitting at rest at	100 "	=	600 "
Energy expenditure and food requirements for the day		=	2640 "

If for the eight hours of typewriting there was substituted a similar period of cross-country walking at three and one-half miles per hour, the daily expenditure would amount to 3,800 kilocalories. A student who spends the day attending classes and walking to and from them, and who devotes his evenings to study or the theater, expends some 2,100 kilocalories (8000 B. T. U.). The daily expenditure of various trades has been estimated at the following averages—which are subject to wide variations:

TABLE II

TOTAL ENERGY EXPENDITURE PER DAY OF MEN ENGAGED IN VARIOUS TRADES

	Kilocalories per 24 hours	B.T.U. per 24 hours
Shoemaker	2,000–2,400	7,800– 9,360
Carpenter or Mason	2,700–3,200	10,530–12,480
Farm Laborer	3,200–4,100	12,480–15,990
Excavator (work with pick and shovel)	4,100–5,000	15,990–19,500
Lumberman	5,000–6,000	19,500–23,400

Running at the rate of five and one-fourth miles per hour a man will go approximately fifty miles on an energy expenditure of 19,000 B.T.U., the heat equivalent of one pound of fat and approximately that of one *pint* of gasoline.

The Thyroid Gland and Regulation of Basal Metabolism.

The basal metabolism is a physiological constant; there must be, therefore, some mechanism which serves as a governor. The internal secretion of the thyroid gland furnishes, in part at least, the necessary stabilizing influence. Internal secretions have been referred to in connection with the pancreas and the regulation of sugar utilization. The thyroid gland is situated in the neck. It has two lobes, one on each side of the trachea or windpipe just

below the larynx, connected by a narrow strip which crosses the front of the trachea. The whole gland weighs approximately thirty to forty grams (one to one and one-half ounces), but in the diseased state of goiter it may be enlarged to many times this weight. The most significant fact regarding the internal secretion of the thyroid is that it contains iodine. The body must be supplied with a certain small amount of iodine in order that the

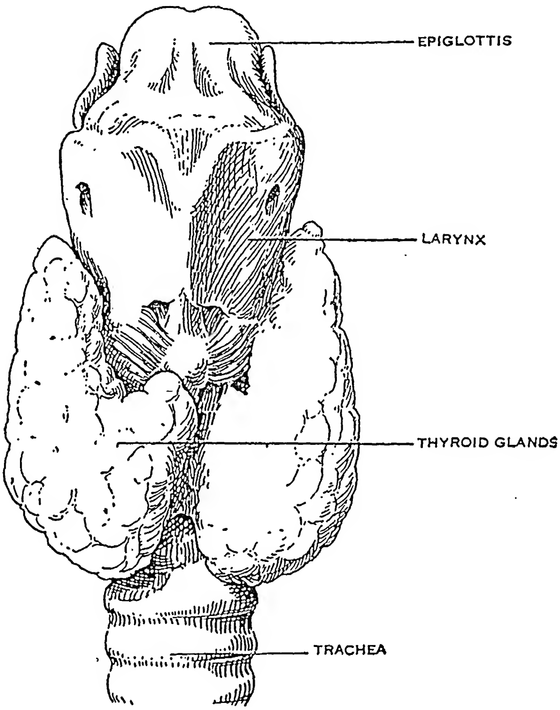

Figure 12. Thyroid Gland.

internal secretion may be formed; the iodides are thus among the foodstuffs necessary for the proper growth and functioning of the body.

The secretion of the thyroid gland continually enters the blood. If a normal amount is secreted basal metabolism is normal. If the secretion is abnormal in amount the basal metabolism is correspondingly affected. The secretion of the thyroid gland exerts an influence over other functions of the body beside the basal metabolism. The symptoms which are induced by abnormal secretion

constitute definite diseases. Diminished or hyposecretion gives rise to cretinism or myxedema, and excessive or hypersecretion to exophthalmic (pop-eyed) goiter.

Cretinism.

Cretinism is a disease which occurs in children in whom there is an insufficient amount, or an entire lack, of the thyroid secretion. It is named from the island of Crete, where such dwarfs, in

Figure 13. A Cretin.
About thirty-five years of age.

ancient times, were common. There are two forms of the disease, the sporadic and endemic. The first includes those children in whom the gland has failed to develop, and since it is a constitutional defect this form of the disease may occur among children in any locality. Endemic cretinism, on the other hand, is the form which occurs among children who live in a locality where iodine is deficient in the drinking water. These localities are known as goiter districts.

A child afflicted with cretinism is of stunted growth and dull mentality. The face is large and bloated, the mouth is held partially open and the tongue hangs out. The abdomen is swollen, the legs are thick and short. Growth may stop with a height of three or four feet even though the cretin may advance in age to adult years. The backward mental state frequently lapses into imbecility.

The deficiency of thyroid secretion, from which a cretin suffers, can be supplied by feeding the thyroid gland taken from slaughtered animals. The dried extract of this gland is sold as a medicine in the form of tablets. If the administration is started when the child is young, the effects are marked; in the period of a few months a stupid, malformed creature changes to a bright, normal, and rapidly growing child. The administration of the thyroid extract must be continued throughout life, or the condition of myxedema develops.

Myxedema.

Myxedema is the disease which a subnormal secretion of the thyroid produces in an adult. In most cases the cause for the deficiency is not known. Persons afflicted show an inelastic swelling of the skin which also becomes dry, coarse, and roughened; the hair falls out. There is slowness of thought and movement. The physiognomy is altered; the features become swollen and coarse, the lines of expression are obliterated, the mouth becomes enlarged, the lips are thickened, and the nostrils broadened. The body increases in weight and is ungainly in appearance. The voice is hoarse. The basal metabolism is below the normal value. As in cretinism, the administration of thyroid extract causes the symptoms to disappear; in a comparatively short time the face loses its brutish appearance, the hair commences to grow, and the mental functions become normal.

Exophthalmic Goiter.

The condition of exophthalmic goiter is produced by an excessive amount of internal secretion of the thyroid and is the opposite of myxedema. The body loses weight, the skin is flushed and moist with perspiration, the heart beats rapidly, and the hands

and tongue tremble. Intense emotional excitement follows slight provocation. The basal metabolism is raised above the normal value; in some to more than double. The characteristic protrusion of the eyeballs, from which the disease receives its name, gives to the face, in severe cases, an expression of agitation or distress. Persons suffering from exophthalmic goiter are quick in their movements, but fatigue readily. The administration of thyroid extract aggravates the symptoms of the disease and will produce them in an otherwise normal person. The extract is sometimes injudiciously taken by fat women to reduce weight; but unless their corpulence is due to myxedema, which is comparatively rare outside of goiter districts, the consequences may be serious, for along with the loss of weight the severe nervous symptoms of exophthalmic goiter develop. Thyroid extract disguised under various trade names has been sold as a patent medicine for reducing purposes.

Exophthalmic goiter is a fairly common disease in all regions. It occurs more often in women than in men. In many instances the cause of the disease cannot be discovered; it is generally assumed, however, that various nervous influences such as worry, excessive social activities, nervous strain, disappointment in love, and fright are predisposing factors. The rate at which the internal secretion of the thyroid is produced is influenced by the emotional state, and the increase may in turn account for some of the bodily phenomena which accompany emotions. The condition of those who suffer from exophthalmic goiter is aggravated by any excitement, while a cure sometimes follows prolonged rest in bed. If the disease does not respond to the rest treatment, operation is usually resorted to, and either a portion of the gland is removed or some of the blood vessels which supply it are tied off.

Goiter and Iodine.

Goiter is a term which applies to any chronic enlargement or increase of activity of the thyroid gland. In exophthalmic goiter the enlargement is not conspicuous. There is another form known as simple goiter in which the gland may enlarge to such an extent that it projects beyond the chin or may interfere with

breathing by pressure upon the windpipe. This form of goiter is not associated with excessive internal secretion; nor does it usually give rise to any ill effects except the deformity of the neck. Simple goiter, like the more serious condition of endemic cretinism, is commonly caused by lack of iodine in the drinking water; the difference between the two conditions is probably due to different degrees of iodine starvation. Simple goiter may be considered as an attempt on the part of the body to compensate for the iodine insufficiency through the production of a larger gland. Goiter is not very common in most parts of America, although it occurs oftenest in the region of the Great Lakes and particularly in Wisconsin and Michigan. In Switzerland, in the mountains of Germany, Austria, and France, the disease is prevalent and there are numerous other goiter districts in the world. Frequently the goiter disappears in those who leave the district and go to places where the drinking water contains more iodine. The administration of iodine in the form of iodides prevents the development of the disease.

CHAPTER V

THE COMPLETE NORMAL DIET

A COMPLETE diet is one which provides all essential foods in the amounts needed both for the energy expenditures and for the maintenance of the body. More specifically the requirements are: (1) Fuel foods, (2) protein, (3) minerals, (4) vitamins, and (5) roughage.

Supply of Fuel Foods.

The expression "food requirements" has been used in previous sections for the calorific value of the diet to balance the energy expenditures. For example, if a man during twenty-four hours expends 2,250 kilocalories (9,000 B.T.U.), this energy can be supplied by a food intake having this heat content. This amount of energy could be derived from 247 grams of fat or 550 grams of carbohydrate (see Chapter I). We do not, however, live on chemically pure dried foodstuffs. With the exception of some of the fats and such purified materials as sugar or cornstarch, the common foods not only contain various proportions of carbohydrates, fats, and proteins but also other substances such as water and inorganic salts from which no energy can be derived. In order to convert food requirements expressed in terms of heat into the amount of the various foods eaten in a mixed diet in their normal moist form, it is necessary to know the calorific value of the common foods. This information is set forth in extensive tables issued by the United States Department of Agriculture, and furnished on request. The table given below presents the average nutrient composition and fuel value for some of the more common foods.

From this table it is seen that butter has the highest fuel value of any of the foods given; bacon ranks second. The salad vegetables such as lettuce and cucumbers have the lowest fuel value, but the oil dressing with which they are customarily served may make a considerable calorific contribution. The vegetables as

TABLE III

TABLE SHOWING THE APPROXIMATE NUTRIENT CONTENT AND FUEL VALUE OF SOME COMMON FOODS

Food	Protein, per cent	Fat, per cent	Carbo-hydrate, per cent	Kilo-calories per pound (or per pint of fluid)	B.T.U. (approximate) per pound (or pint of fluid)
Fruit:					
Grapefruit and oranges...	.5	.4	8.6	170	650
Apples..................	.4	.5	10.8	214	800
Bananas.................	.8	.4	14.3	290	1,100
Vegetables:					
Cucumbers or lettuce.....	.1	.3	3.0	83	325
Cabbage.................	1.6	.3	5.6	143	560
String beans............	2.1	.3	6.9	176	685
Peas....................	3.6	.2	9.8	252	980
Potatoes................	1.8	.1	14.7	302	1,180
Baked beans.............	6.9	2.5	19.8	583	2,200
Cereal Products:					
Bread...................	9.6	2.2	57.3	1,284	5,000
Rice....................	8.0	.3	77.9	1,591	6,200
Macaroni................	13.4	.9	74.1	1,625	6,300
Shredded wheat..........	10.5	1.4	77.9	1,660	6,500
Crackers................	11.0	8.5	71.1	1,835	7,200
Meat Products:					
Oysters.................	6.2	1.2	3.7	228	900
Chicken.................	12.8	1.4		289	1,150
Lean beef...............	21.9	5.4		617	2,400
Veal....................	20.3	7.7		683	2,600
Bologna or sausage.......	18.7	17.6	.3	1,061	4,000
Smoked ham, lean........	19.8	20.8		1,209	4,719
Mutton..................	15.6	30.9		1,543	6,000
Moderately fat beef......	21.9	35.6		1,721	6,700
Bacon...................	10.5	64.8		2,840	11,000
Pea Soup Canned..........	3.6	.7	7.6	232	900
Milk (whole).............	3.3	4.0	5.0	314	1,200
Milk (condensed sweetened).	8.8	8.3	54.1	1,480	6,000
Eggs (an egg weighs 2 ounces)	11.9	9.3		594	2,300
Honey...................	.4		81.2	1,481	5,800
Butter..................	1.0	85.0		3,491	13,600

a whole have a low heat value, with baked beans highest at 583 kilocalories per pound, and peas and potatoes next at about one-half this value. The cereal products such as bread, rice, and macaroni range between 1,200 and 1,800 kilocalories per pound. The fuel values of the various meats are determined largely by the amount of fat which they include; they contain only small amounts of carbohydrate and the per cent of protein does not vary greatly. The heat value of a pound of moderately fat beef is nearly three times as great as that of a similar quantity of lean beef. A half pint glass of milk furnishes 200 kilocalories, and two eggs give the same amount of heat. A one-ounce slice of bread yields 80 kilocalories; when spread with half an ounce of butter the heat value is doubled, while the addition of a moderate layer of honey, half an ounce, brings the total to some 250 kilocalories. Eight or nine slices of the buttered and honey-coated bread is sufficient to satisfy the daily fuel needs of an office worker, but does not supply all of the other requirements of a complete diet.

Supply of Protein.

The minimum supply of protein necessary for the maintenance of the human body has been discussed in detail under the section devoted to the metabolism of protein (see Chapter IV). The per cent of protein in some of the more common foods is given in the table above. Meat contains the highest percentage of protein; with the exception of bacon, the value averages approximately 20 per cent. This protein, moreover, can be reconstructed without loss into that of human flesh, as is also the case with the proteins from eggs and milk. The cereal products and also beans contain approximately one-half as much protein as meat. In these vegetables, however, the amino acids are not in the same proportion as in human protein, and they must be taken, therefore, in greater quantities than the protein of meat, in order to supply the necessary minimum of 50 grams of human protein.

Supply of Mineral Foodstuffs.

The body requires for its growth, repair, and proper function a number of elements usually classed as minerals. With the exception of calcium and iron these are supplied in adequate

amounts by any mixed diet. Table salt supplies sodium and chlorine. Everywhere near the sea, iodine is contained in the drinking water. Two elements, calcium or lime and iron, are, however, sometimes deficient in the ordinary diet.

Calcium.

It is lime salts, the carbonate and tribasic phosphate of calcium, which give stiffness to the bones. Calcium is also an essential constituent of the blood. There is a greater weight of calcium in the body than of any other mineral element. Calcium is constantly excreted from the body; it has been estimated that an average of 1 gram (15 grains) a day is needed to replace the loss; growing children and women who are pregnant or nursing require an even greater amount.

There is a wide difference in the calcium content of various foods; meat is exceedingly poor in calcium, while milk is so rich in this element that less than one quart supplies the daily need. Cheese, egg yolk, and to a less extent dried beans contain more calcium than do most foods, but milk remains the main source. To obtain the essential amount of calcium does not mean that milk must be taken as a fluid; milk enters to a great extent into the culinary preparation of pastry, soups, creamed vegetables, custards, ice cream, and many other dishes. The milk supply for a family or any group of persons who are served from a common kitchen should average a quart a day per person.

Iron.

Iron is a constituent of the red coloring matter of the blood, hemoglobin; an insufficient supply may lead to a disease known as anemia, in which the blood contains less hemoglobin than it normally should (see Chapter VI). After loss of blood from any cause the body needs for a time more than the ordinary supply of iron in order that new hemoglobin may be formed. It has been estimated that 15 milligrams (¼ grain) of "food iron" each day is sufficient for the average needs. The iron requirement for women, by reason of the menstrual flow, is somewhat higher than for men. By "food iron" is meant iron which occurs in organic combination as a normal constituent of foods. The

term is used in distinction to inorganic forms of iron such as are found in some drinking water or the commercial salts of iron such as the chloride. Food iron appears to be more readily adapted to the needs of the body than are the inorganic salts, although certain of the latter are sometimes used effectively in the treatment of anemia.

Egg yolk, molasses, whole wheat, dried beans, peas, spinach, and prunes are foods particularly rich in iron; the relative content in equal weights of the foods is in the order named. Meat is not included here for the reason that its iron content varies nearly in proportion to the amount of blood which it contains. Lean meat from which the blood has not been washed is an excellent source of iron. Jews who eat *kosher* meat are often anemic. Milk is low in iron and in fact does not contain an amount sufficient to supply the needs of a nursing infant. The deficit in this case is compensated by a supply of iron which is stored

TABLE IV

SHOWING THE WEIGHT OF SOME COMMON FOODS WHICH WILL SUPPLY 15 MILLIGRAMS (¼ GRAIN) OF FOOD IRON

Food	Weight of food required to supply 15 mg. of iron	
	Ounces	Grams
Molasses	6	180
Dried beans	7	210
Dried peas	8	240
Shredded wheat	9	270
Spinach	11	330
Oatmeal	11	330
Prunes	11	330
Olives	11	330
Lean beef	11	330
Eggs	16	480
Boston brown bread	16	480
Graham bread	16	480
Raisins	24	720
White bread	48	1,440
Milk	200	6,000

in the body of an infant prior to its birth: the necessity of furnishing this supply during pregnancy devolves upon the mother. The widely advertised virtue of raisins as a source of iron is not substantiated by fact. Table IV gives the comparative weights of some common foods which will supply 15 milligrams of food iron.

Supply of Vitamins.

Animals which are fed upon chemically pure foodstuffs cannot be made to grow, or in some cases even be kept in health, although the diet satisfies the needs for energy, protein, and minerals. Evidently, natural foods contain some unknown substances which are essential to the well-being of the body: these substances are called vitamins. The word "vitamine" was coined in 1911 in the belief that chemically these unknown substances were "amines": as the prefix "vita" signifies life, "vitamine" thus meant an amine essential to life. This idea of the chemical structure is no longer held and many people now use the abbreviated term "vitamin." Although not named until recent years, some conception of these beneficial substances existed a century ago, for even then fruit juices were used to treat scurvy, a disease now known to be due to a deficiency of one of the vitamins.

The three principal vitamins are designated by the letters A, B, and C. (Vitamins D and E have also been described, but are less well known than those listed here.) They are distinguished by the symptoms which follow a diet deficient in any one.

The so-called "fat soluble" vitamin A is the growth-promoting vitamin. Young animals deprived of this vitamin soon cease to grow. The nutrition of all parts of the body is affected: the teeth do not form normally, the eyes become sore and infected, and there is a generally decreased resistance to disease: its absence is also thought to play a part in rickets, a disease of the bones (Chapter XXIII). The need for vitamin A is much greater for the growing person than for the adult. This vitamin is stored in the body whenever the diet contains an excess over the immediate need, and the amount stored appears to be a factor in the general bodily vigor and ability to resist disease: in the

female during reproduction and nursing this store may be depleted.

The so-called "water-soluble" vitamin B is essential in the nutrition at all ages, although of minor importance in promoting growth. Lack of vitamin B causes loss of appetite and a generally run-down state which in severe cases leads to the disease beriberi. More than 50,000 cases of this disease developed in the Japanese army during the war between Japan and Russia. The diet for the army consisted largely of polished rice; the thin skin of natural rice contains vitamin B, and in the process of polishing this skin is removed, so that the polished product contains no vitamin. Beriberi is common among the Malays, Chinese, and Filipinos; it also occurs in some parts of South America and in the West Indies; there have been several severe outbreaks among inmates of asylums in the United States. Persons afflicted with beriberi are paralyzed, the muscles become painful and waste away, the heart is frequently affected, and death results unless the diet is altered.

Lack of vitamin C is followed by scurvy. This disease was formerly very common among sailors who lived for long periods on a diet of dried and salted food. Nearly a century ago it was found that the addition of fruit juice to the diet prevented and cured the disease. The men in the British navy are to this day designated as "lime-juicers" from the fact that the sailing regulations required that this source of vitamin C be carried on all vessels and administered to the crews. Scurvy occurs occasionally in charitable institutions; it is found in settlements of low-grade foreign population, such as the Hungarians, Bohemians, and Italians in the mining district of Pennsylvania. Scurvy may occur in infants if fruit or vegetable juice is not included in their diet.

Scurvy is insidious in its onset; there is loss of weight, progressive weakness, and pallor. The gums become swollen and spongy and bleed easily. The teeth may become loose and even fall out; the breath is very foul. Small hemorrhages occur beneath the skin, sometimes forming open sores. The mind is depressed and indifferent.

In recent years much publicity has been given to information about vitamins; the impressions left are sometimes misleading. In order to insure growth and vigor and to prevent disease, the diet must contain the vitamins A, B, and C. One, two, and sometimes all three vitamins are present in many of the common natural foods. It is entirely unnecessary for anyone to use the preparations sold as a source of vitamin. Yeast is widely advertised for such a purpose; this substance contains about as much of vitamin B as raw cabbage, but it has little, if any, of types A and C.

Tomatoes, either canned or raw, are one of the best sources of vitamins; lettuce and cabbage also furnish vitamins of all three types. Orange juice, lemon juice, grapefruit, and raw onions are good sources of vitamins B and C. Butter, spinach, and milk furnish type A in abundance. Oleo—or nut margarine, in contrast with butter, contains but little of vitamin A. Margarine is not a good substitute for butter or milk for growing children or for women during pregnancy and nursing, at which time an abundance of vitamin A is needed. Sauerkraut, polished rice, sugar, and olive oil contain no vitamins.

The Supply of Roughage.

By "roughage" is meant food material having a large indigestible residue which will give bulk to the material in the intestines and thus promote their movements. The term is derived from the feeding of farm animals, where it applies to fodder in distinction to the richer grain foods. Roughage is supplied in the human diet by green vegetables and by the pulp of fruits; the salad vegetables are a particularly good source of roughage. Bran, and also seaweed under the name of "agar," are sold specifically as roughage; but the green vegetables are preferable, for they supply minerals as well as roughage. The exact amount of roughage necessary in any diet cannot be accurately estimated; it should be included daily in amounts sufficient to cause movement of the bowels. To this end salad, green vegetables, and fruit (not fruit juice alone) are necessary constituents of the daily diet.

Calculation of the Adequacy of a Diet.

The needs of the body for protein, minerals, vitamins, and roughage are independent of the energy expenditures. A girl working at a sedentary occupation, as in an office, needs as much of these substances as does a lumberman engaged in his heavy labor; a woman during pregnancy and during the time she nurses her child needs even more.

The following calculations are not intended as a guide to diet, but merely to show the method of estimating the adequacy of a diet.

In the section on the fuel value of food it was stated that 8 slices of bread spread with butter and honey would supply 2,000 kilocalories (8,000 B.T.U.), and would therefore satisfy the daily needs of fuel for the average office worker. Let us consider now the inadequacies of this diet:

From the per cent of nutrients given in Table III, and from the weight of eight slices of bread, butter, and honey, the amount of protein is calculated as follows:

250 grams (8 ounces) of bread containing 9.6 per cent protein = 24 grams
125 grams (4 ounces) of butter containing 1.0 per cent protein = 1.25 grams
125 grams (4 ounces) of honey containing 0.4 per cent protein = 0.5 grams
Total protein = 25.75 grams

It was stated in the section dealing with protein requirements that 50 grams of meat protein are the daily minimum; the diet under question furnishes approximately half of this amount. Furthermore, practically all of this protein is derived from bread. Because of its deficiency in certain amino acids, 127 grams of bread protein is required instead of the basic 50 grams which refers to a protein complete in all the amino acids necessary for human protoplasm. The protein in 1½ quarts of whole milk, 49.5 grams would, however, make up the protein deficiency in the diet under discussion. The milk would also add 900 kilocalories (3,600 B.T.U.), so that in order to maintain the calorific total approximately 3½ slices of bread, butter, and honey would have

to be omitted. The protein would still remain adequate after this omission.

The diet under discussion as altered to satisfy the requirement for protein now consists of 4½ slices of bread, butter, and honey and 1½ quarts of milk. Consider next the need for the minerals, calcium and iron. The first is satisfied from the milk, since one quart of this supplies the daily minimum of calcium. Iron, however, is almost entirely lacking. This deficit could be made up by substituting molasses for the honey on the bread; the calorific value and protein would not be altered.

The diet as thus altered is still deficient both in vitamins B and C (butter supplies vitamin A) and in roughage. Two medium-sized apples would remedy the deficit in vitamins and roughage, and in heat value would take the place of one-half a slice of bread, butter, and molasses. The diet for the day now considered as complete consists of the following:

4 slices of bread, butter, and molasses
1½ quarts of milk
2 medium-sized apples

This collection of food will supply 2,000 kilocalories (8,000 B.T.U.), slightly over 2 ounces of protein equivalent to that of meat, and sufficient minerals, vitamins and roughage for most persons. A greater requirement for fuel could be supplied by the addition of any type of food desired (even candy), and its addition would not alter the basic requirements which have been fulfilled.

The diet discussed here is chosen merely by way of illustration: similar calculations would apply to any other selection of foods. The necessary bulk could have been obtained equally as well from cabbage, string beans, lettuce, or other fibrous vegetables, and the protein from eggs or any one of a variety of meats.

If a reduction in the weight of the body is desired, the limitation of the diet should be made only in the supply of carbohydrates and fats, particularly the latter. The harmful effects which sometimes result from dieting are largely the result of lack of sufficient protein, vitamins, or minerals in the curtailed supply of food.

Constancy of Body Weight.

The weight of an adult remains fairly constant over long periods. There are daily fluctuations of a few pounds which are due mainly to the variations in the water content of the body; the drinking of a quart of water increases the weight two pounds, while an equal decrease follows the urination of a like amount of fluid; the loss by perspiration during vigorous exercise such as a football game may amount to from four to six pounds or even more. The weight may fall during a period of illness, but is regained during convalescence. In some persons a gain or loss of weight accompanies change of environment or occupation; when the new conditions have become established the weight is again maintained at a constant level. The approximate constancy of the body's mass is indicated by the fact that nearly everyone can tell his own weight within a few pounds even though he has not determined it on a balance for several months.

Aside from the large but temporary fluctuations due to variations in the water content, the weight of the adult body expresses the balance between energy expenditure and food intake. If the expenditure exceeds the intake, fat is removed from storage in the body and burned, and a decrease of weight occurs. If the food intake (expressed in heat units) exceeds the expenditure, fat is formed and stored, and the body gains weight. The nicety with which the food intake is automatically regulated is illustrated by the fact that if a man were to drink two glasses of milk a day in excess of the food actually needed to balance his energy expenditure, and if appetite and digestion permitted the addition, at the end of a year the gain in weight would amount to over twenty pounds. The reason that milk does not increase his weight is that he would automatically cut down on other food.

Regulation of Food Intake by Hunger and Appetite.

The expenditure of energy is variable from day to day and determines the need for fuel foods. The adjustment of the intake of fuel to the varying needs is accomplished through the sensations of hunger and appetite.

Hunger and appetite are distinct; the former is a basic function which definitely states the need for food without discrimina-

tion; appetite is a refining influence and specifies the form of food chosen to satisfy the hunger. Appetite is related to previous sensations of sight, taste, and smell of food and has a mental quality which is acquired by experience. Appetite indicates primarily the forms of food which have been found previously to be nutritious and free from harm; hunger makes no distinction between clean and putrefied meat; appetite does. Appetite may exist apart from hunger, as when one eats dainties merely to please the palate; likewise hunger may override the appetite and force the taking of food which under ordinary circumstances is distasteful and even nauseating.

Hunger establishes a total calorific value to which, over a period of several days, the food intake must conform; the choice of food is left to the appetite. Consequently, some persons satisfy their needs on a small quantity of highly nutritious material, while others, equally hungry, eat a large quantity of food with a low calorific value. A meal made up, for example, of moderately fat roast beef, potatoes, spinach, lettuce, and bread and butter can be eaten in two ways, both giving the same calorific total. One person may eat the meat with its fat, half the bread, and all the butter, and appear a "light eater," for he has left half the bread, the potatoes, the lettuce, and the spinach. Another person, a so-called "heavy eater," may leave only half the butter and all the fat of the beef; nevertheless, he has eaten no more in calories than the "light eater," for the lettuce and spinach contribute little fuel, and the extra potatoes and bread barely equal the fat of the beef and the extra butter.

When the appetite for some particularly tempting food exceeds the demands of hunger, and the amount taken is more than sufficient to balance the energy expenditure, the excess is compensated for by a decrease in the food intake at the next meal; otherwise the symptoms of surfeit and indigestion may develop. The lack of hunger at the time of the evening meal following a holiday dinner is a familiar phenomenon.

Hunger.

The sensation of hunger commences with a vague feeling of emptiness in the region of the stomach; if food is not obtained,

the sensation increases to a dull ache or gnawing sensation which is highly uncomfortable. During starvation the sensation of hunger lasts only for the first few days; then it gradually decreases, and finally almost disappears. It is stated by those who have starved for long periods that although the hunger sensation is strong enough to cause discomfort, it is not painful enough to interfere seriously with work. Starvation cannot, therefore, be designated as actual suffering.

The sensations of hunger are caused mainly by intermittent muscular contractions of the stomach; the intensity of the sensation varies with the vigor of the contractions. Hunger may commence before the last meal has left the stomach and in most persons the time of onset is largely a matter of habit which has been developed in consequence of a regular meal hour; the habit acquired is analogous to the movements of the large intestine which bring about defecation at a regular time each day.

The volume of the food taken has an influence upon the immediate appeasing of hunger. Thus a large portion of soup satisfies the hunger for that time, but the sensation soon returns. A similar temporary stilling of hunger is accomplished by tightening the clothing so that the stomach is pressed upon. The hungry man pulls his belt tight to ease the gnawing pain, while the gourmand loosens his vest so that his appetite may be unhampered by satiation. Many women gain in weight for a period after having borne a child, and this is due in part at least to the relaxation of the abdominal muscles which then fail to exert one of the normal checking influences upon the intake of food; for the opposite reason tight lacing is sometimes followed by a loss in weight.

The hunger contractions of the stomach are stopped momentarily by the mere taking of food into the mouth; a hungry man finds solace in chewing nonnutrient substances such as leather. Contrariwise, the appetite of one who is recovering from an illness is fickle and disappears after a few mouthfuls of food.

The length of time that food stays in the stomach has an influence upon the time which will elapse before the recurrence of hunger; the sensation returns soon after a meal made up largely of carbohydrate, such as potatoes and crackers, but less quickly

after one of meat; and only slowly after a meal high in fat. Fat gives what is called "richness" to the diet; it stays the longest in the stomach, and appeases the hunger for a greater time than any other form of food. Although many factors appear to modify hunger, the effects are only temporary; the basic demand remains and the calorific need is balanced in the ensuing meals.

Hunger and Appetite as Guides to Diet.

One point in connection with hunger is of extreme importance in its relation to a complete normal diet. Hunger is mainly adjusted to the fuel needs of the body and generally makes less specific calls for the minerals, proteins, and vitamins necessary for growth, maintenance, and repair. These essential factors in the diet depend to a great extent upon the discretion of the individual. Prepared foods, such as white bread, are often deficient in some of the natural constituents. The choice of a diet has become a matter of importance. The customs and traditions which govern the preparation and combination of foods for the table express the accumulated experience of past generations, thus generally tend to guide the individual into food habits which conform more nearly to a complete diet than the appetite alone, or theories of food faddists, would dictate. Nevertheless, the experience of the past cannot guide in the use of foods which were unavailable a generation ago, but are now common articles of diet. Furthermore, the living habits of the people have changed. The office worker requires as much bulk, protein, minerals, and vitamins as does the laborer; but their total food intake varies with their respective expenditures of energy. Upon the same choice of foods, therefore, the heavy worker fares the better of the two, for any deficiency in essentials is accentuated in inverse proportion to the amount of food eaten.

The "law of the minimum" holds in regard to the diet, and any one of the necessary elements of nutrition may become the limiting factor of the diet. An insufficiency of lime or iron in the food is as deleterious as is lack of fuel to balance the energy expenditure.

The purchase and preparation of food should be adjusted primarily to the requirements for minerals, vitamins, and bulk; the

supply of fuel and generally of protein may be left to the dictates of appetite and supplied in a manner suited to the economic conditions. True economy in the purchase of foods can be practiced only in the selection of the fuel foods; a saving at the expense of vitamins, minerals, or protein is false economy. On this plan the first requirement is vegetables, milk, and fruit; while breadstuffs, meat, fat, and sweets may be added to suit the taste and purse. For an equal price, cereals furnish the greatest fuel value, after which comes in order fats and meat.

Thirst.

The sensation of thirst controls the intake of fluids; it has no relation to hunger and does not arise from the stomach. Thirst is determined by the dryness of the mouth and pharynx. The salivary glands and the minute glands imbedded in the mucous membrane of the mouth and pharynx keep this area moist; the amount of fluid secreted is determined largely by the water content of the tissues of the body. Thirst may be produced independently of the supply of water in the body by any factor which dries out the mouth and throat, such, for example, as public speaking, breathing through the mouth, or strong emotion. On the other hand, thirst is momentarily relieved by rinsing the mouth with water, even if none is swallowed, or by increasing the flow of saliva by sucking a lemon.

CHAPTER VI

THE CIRCULATION AND ITS DISEASES

UNICELLULAR organisms live immersed in water. Through the surface of the body they draw in food and oxygen dissolved in the water, and return carbon dioxide and other wastes. The presence of the water about these organisms is essential for their existence. Every active cell in the body of man is likewise bathed in fluid, lymph, which is derived from the blood. From it the cells take food and oxygen and return carbon dioxide and solid waste in solution. The blood is a specialized ocean, a remnant of the primordial ocean in which all life was evolved. The blood is salty, for it has retained the salt in the same proportion as that of the ocean of which it was once a part. The large volume of stagnant fluid has been replaced in the body by a small volume kept in active circulation. At every round of the circulating blood its entire volume is spread out in a thin layer and exposed to the air in the lungs. From this air the blood absorbs oxygen while carbon dioxide diffuses from the blood to the air. Without this exchange of gases, energy expenditure is impossible.

Food is supplied to the blood from the digestive tract and from the body's labile stores of fat and sugar. The fluid of the blood is constantly renewed by a stream of water which flows into it from the liquid which we drink. Secretion of watery solutions through the skin and kidneys in the form of sweat and urine, carries away the solid wastes, and maintains the normal volume of the fluid medium of the body.

Properties of Blood.

Blood is a red opaque fluid. When examined under the microscope it is seen to consist of a faintly yellow fluid, the plasma, in which float a great number of solid elements, the corpuscles, to which the opacity of blood is due. The corpuscles are of two types—the red corpuscles, and the white corpuscles.

A few minutes after blood is drawn from the body it sets into

a jelly-like mass. This clotting occurs through the formation of minute threads of fibrin, which separate from the plasma. The net of fibrin permeates the fluid and incloses in its meshes the red and white corpuscles. The fibrin gradually shrinks, the corpuscles are restrained in the net, and a fluid is pressed out. This fluid is called serum and is plasma from which fibrin has separated during clotting. Serum does not clot.

Red Blood Corpuscles.

The red corpuscles are thin, circular disks, slightly biconcave. Their diameter is between 7 and 8 microns, or .00028 to .00032 of an inch, and their thickness is one-fifth as much. One cubic millimeter of normal human blood contains about 5,000,000 red corpuscles; a cubic inch would contain nearly 16,000 times as many. The total surface of the red blood corpuscles in 1 cubic millimeter of the blood is 640 square millimeters, or about 1 square inch. The body contains approximately 5 liters of blood; the total number of red corpuscles, therefore, is about 25,000,000,000,000, and their total surface 3,200 square meters, or .8 of an acre. The surface of a man's body is 2 square meters or less. The red blood corpuscles carry oxygen; the whole of this enormous surface is exposed for free diffusion of gases from and into the air in the lungs at each round of the circulation.

The red blood corpuscles consist of a delicate sac or sponge containing red material known as hemoglobin. Hemoglobin is a protein compound containing iron; it is by means of this iron that it performs its function. When exposed to the air hemoglobin absorbs oxygen and oxyhemoglobin is formed. This reaction occurs as the blood passes through the lungs. When the blood reaches the tissues a part of the oxygen diffuses out and is consumed in the activities of the cells. In consequence of this loss of oxygen some of the oxyhemoglobin is reduced to hemoglobin. Oxyhemoglobin has a bright vermilion color; hemoglobin from which oxygen has been withdrawn is a deep purple. The blood in the arteries is bright red and so is that shed from a wound, for the exposure to the air converts any hemoglobin present into oxyhemoglobin. The blood in the veins has been passed through the tissues and therefore contains less oxygen.

The bluish color of this blood is apparent in those veins which run just beneath the skin, as on the back of the hand or on the inner surface of the elbow.

The red corpuscles are heavier than the plasma, or serum, and when blood is allowed to stand in a vessel and the clotting is prevented they settle to the bottom. About two-fifths of the volume of the blood is made up of red corpuscles. The red blood corpuscles are very sensitive to a decrease in osmotic pressure. The blood has an osmotic pressure equivalent to about 0.9 per cent of sodium chloride. If distilled water is added to the blood the corpuscles are first distended and then ruptured and the hemoglobin is discharged. Blood is said to be "laked" when the hemoglobin has been thus set free from the corpuscles. Hemoglobin freed in the circulating blood is passed out through the kidneys and gives to the urine a blackish color; thus in a severe type of malaria occurring in Africa, in which part of the blood is laked, the disease has been named from the color of the urine, "black water" fever.

Destruction of Red Blood Corpuscles.

Red blood corpuscles are continually destroyed in the body. The length of life for a red blood corpuscle is estimated as approximately ten days, so that 10 per cent of the corpuscles are broken down each day. To replace those destroyed, new corpuscles are manufactured in the red marrow of the bones. This type of marrow fills those bones which have a spongy interior. Yellow marrow found in the shafts of the long bones, those of the legs and arms, is fat. The heads of these bones, and the interior of all other bones, are filled with red marrow.

The iron from the corpuscles broken down in the body is separated out of the hemoglobin by the liver. The remainder of the hemoglobin molecule is passed into the bile and gives to that secretion its characteristic yellowish-green color. The iron recovered is used to form hemoglobin for new corpuscles. A small amount of iron escapes the recovery process in the liver and is excreted in the bile. To replace this loss iron is taken in the food. If the iron is not supplied in the diet a deficit develops, and after a time the normal formation of corpuscles is pre-

vented. As the destruction of corpuscles continues without interruption, the number in the blood is decreased. A condition of insufficient red blood corpuscles from this or other causes is called "anemia."

Although some 10 per cent of the red blood corpuscles are destroyed each day, this normal process is different from a hemorrhage involving an equivalent loss. In the case of a hemorrhage the iron of the hemoglobin is not salvaged by the liver. It can only be replaced by iron taken in the food.

White Blood Corpuscles and Infection.

The number of white corpuscles circulating in the blood is variable. Normally there are from 8,000 to 9,000 per cubic millimeter, or one white to every 500 or 600 red corpuscles. There are many more stored in the body which can enter the blood when needed. The white corpuscles are larger than the red and are of various shapes. They are classified, according to their appearance, into several groups. The white corpuscles serve to transport certain substances in the blood; but their main function is to destroy and remove foreign materials, such as bacteria. The white corpuscles are freer in their activities than are the red. They can change their shape and perform independent movements. They are, in fact, virtually independent unicellular organisms living in the blood. The majority are stored in the so-called lymph glands. They may be likened to an army of soldiers; a few are regularly on sentry duty in the blood vessels, while a large reinforcement awaits mobilization when need arises, as when there is a bacterial invasion of the body. The number in the blood then mounts from the normal 8,000 or 9,000 per cubic millimeter to 15,000, 25,000, or even more. If the bacterial invasion is local, the reinforcement is called to the particular spot at which it is needed. Thus when bacteria enter the tissues through a break in the skin, white corpuscles congregate there, work their way through the walls of the blood vessels, and destroy the bacteria. The white corpuscles also die. As the accumulation of dead corpuscles increases, a pocket is formed in the tissue at the point of infection. This pocket either breaks through the skin from the pressure of the

red corpuscles do not pass in and out of the capillary blood vessels. The number of corpuscles in a cubic millimeter of blood taken from any individual remains fairly constant over long periods. This fact is an indication of the uniform volume at which the blood is maintained. Even after a severe hemorrhage the volume of blood is restored to normal in a very short time, although it may be serveral weeks or months before the normal number of red blood corpuscles is recovered. A severe hemorrhage induces great thirst; the wounded man cries for water.

Up to half a century ago the belief persisted that the volume of blood is increased in some disorders and that this supposititious condition induces many ill effects. Under this doctrine of plethora it was the practice to bleed people for nearly every sort of disorder. At one time bleeding was the main occupation of the physician. Monks were bled regularly even when well. Perhaps a high arterial pressure was in those days mistaken for a too large quantity of blood. It is now known that even people with high arterial pressure do not have too much blood and the act of bleeding is rarely resorted to. Nevertheless, it is occasionally practiced as a rapid means of temporarily lowering a critically high arterial pressure.

In water starvation or in the water depletion of severe diarrhea, such as that of Asiatic cholera, the severity of the condition may drain the tissues sufficiently to decrease the volume of the blood. Death may result from this dehydration. If the thirst is satisfied or, in the case of cholera, if adequate water is supplied intravenously, the blood volume is quickly restored to normal.

Coagulation of the Blood.

After any slight injury involving the cutting or tearing of some of the smaller blood vessels, the blood coagulates at the point of its escape; this stops the bleeding. If the blood did not clot, every slight wound would be followed by a continuing and finally fatal hemorrhage. When a large artery is cut coagulation is not sufficient to check the hemorrhage, for the rapidity of the flow prevents the formation of a clot.

accumulation or more often is opened by an instrument. The thick liquid which pours out from the opening is composed of dead corpuscles. It is known as pus.

The formation of pus is always a sign of infection. Unfortunately, the white corpuscles do not respond effectively to all forms of infection; some of the most serious bacterial invasions are not effectively opposed by the white corpuscles. This is true of infection with the bacillus of tuberculosis and the streptococcus which is, par excellence, the organism causing the septicemia, popularly called "blood poisoning," which is often fatal.

Quantity of Blood in the Body and Its Constancy.

The blood makes up about 7 per cent of the weight of the body. Thus a man weighing 73 kilos (160 pounds) has approximately 5 liters or quarts of blood. The normal volume of the blood is maintained with great persistency in spite of various factors which tend to alter it. The tissues of the body act as an enormous reservoir to take up or give back water to the blood to equalize its volume. When water is drunk it passes through the walls of the intestines into the blood; but the volume of the blood is not appreciably altered, for as the water is absorbed a like quantity passes from the blood into the tissues. The kidneys continually secrete fluid which is taken from the blood; but this loss, or one from perspiration, is made up by a return of water from the tissues. When the reserve of fluid in the tissues has been reduced to a certain level the sensation of thirst is aroused.

In maintaining the blood at a uniform volume the water content of the tissues fluctuates. The rate at which urine is excreted and the sensation of thirst act together to minimize these fluctuations and to maintain a normal content of water in the tissues. Contrariwise, when the water content of the tissues is raised considerably, as is the case when a quantity of water is drunk at a time when there is no particular demand for water, the secretion of urine is increased. When the content of water in the tissues is lowered by excessive perspiration, the secretion of urine is diminished.

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While normal coagulation is very important, it is equally important that the blood should not clot in the uninjured vessels. The chemical process of coagulation is complicated and depends upon a number of factors which must act in sequence. If any one of these factors is missing, clotting does not occur. The substance necessary to initiate the process is present chiefly in the so-called blood platelets, minute cells contained in the blood. It is liberated only when the tissues are wounded. Therefore, when blood escapes over a wounded surface it clots.

The essential of clotting consists in the precipitation of a protein in the plasma. The precipitate, fibrin, separates as fine threads which entangle the corpuscles, thus forming a barrier through which fluid cannot pass. Fibrin is precipitated when a substance known as thrombin is formed in the blood. Thrombin arises only when the juices from the cut tissues enter the blood. When blood is drawn with great care to prevent contact with the tissues and collected in vessels coated with oil or paraffin, clotting does not occur or is delayed for a long time. However, a clot forms if this blood is stirred with a rod which is not coated with oil. In this case the substances necessary to initiate the process presumably arise from blood cells which are injured.

Calcium must be present in the blood or fibrin cannot be formed. The clotting of blood is prevented by the addition of substances which precipitate the calcium, such as sodium oxalate, for like the casein which is curdled in milk in making cheese, fibrin is a compound of a protein with calcium.

Hemophilia.

Blood does not clot instantaneously; as the process is complicated, it requires a certain length of time for its completion. Some diseases lengthen the time required for clotting, so that a hemorrhage persists and is difficult to check. This condition usually disappears with recovery from the disease. There are some persons whose blood at all times coagulates with abnormal slowness. They are called "bleeders." This disease, hemophilia, is hereditary; it affects only male members of the family, but it is transmitted only through females. Thus the sister of

a man afflicted with hemophilia, without herself having the disease, may transmit it to her sons. The children of her brother are free from the disease. Hemophilia may exist in many degrees of severity. Those whose blood does not clot at all die in infancy; those who are less seriously afflicted manage to survive ordinary injuries; but they may succumb to one in which a small artery is damaged, as occurs in the extraction of a tooth, or they may bleed alarmingly during a surgical operation.

Thrombosis and Embolism.

Occasionally a clot forms within the blood vessels without any evident injury having occurred. This unusual occurrence is known as thrombosis; the clot is known as a thrombus. The cause of thrombosis is not known, but slowing of the blood flow and disease of the vessel walls are predisposing factors. An abnormal widening of the vessels or pressure upon them causes a slowing of the flow. Thus varicose veins or an aneurism predisposes to thrombosis. Likewise thrombosis is occasionally seen after childbirth. It then occurs in the veins in the mother's legs, for the blood flow in the vessels is obstructed during the birth. Such a thrombus is liable to become infected, producing phlebitis, or inflammation of the vein.

Thrombosis is a serious condition. It usually occurs in a vein. Particles may be broken off and carried to the lungs, shutting off the blood flow through them. Every precaution is taken, therefore, to keep those afflicted as still as possible until the thrombus has grown firmly in place in the blood vessel. A thrombus which has thus broken free is known as an embolus; the resulting condition is embolism. Thus thrombosis of a vein in the leg may cause death from pulmonary embolism. The term embolus is not limited to a floating piece of blood clot in the vessels, but is applied also to any foreign substance which enters the blood and may obstruct its flow. It is possible for an embolus of air to occur; the air may enter an open vein in a wound in the neck. The symptoms of caisson disease arise in part from emboli of nitrogen gas. If the gas collects in the heart in any quantity, death is almost immediate; the heart

valves do not operate except in a liquid; the gas remains in the heart and keeps the blood from entering.

An embolus in an artery is not usually as serious as one in a vein. The arterial blood is strained through the fine capillaries before going into the veins, and an embolus is thus stopped. The flow of blood in the artery supplying these capillaries is obstructed, but in most parts of the body this is not a serious matter, for usually there are communicating vessels through which it can flow. Unfortunately this is not the case in the brain, for the terminal vessels there do not connect freely. Consequently an embolus in an artery of the brain may cut off the circulation of blood to the area which it supplies. The consequences are paralysis, loss of speech or memory, or other nervous disorders, depending upon the location of the area in the brain deprived of blood.

Anemia.

Anemia means, literally, lack of blood, but the term is now applied to those conditions in which either the number of red cells or the amount of hemoglobin is reduced. The blood in anemia is not as red as normal blood; one of the symptoms of anemia is pallor of the skin and mucous membranes, particularly of the conjunctiva of the eye. All skin pallor is not, however, due to anemia. The normal color of the skin is determined in part by its pigments and in part by the quality and quantity of blood which it contains. The pallor of fainting is due to lack of blood in the vessels of the skin, and not to anemia. Certain races, such as the Polish, have a thick but only slightly pigmented skin; consequently they show little color in their cheeks. Other races, such as the Germanic, have for opposite reasons a pink skin. Persons who live under poor hygienic conditions often appear pale, although they may not have anemia. The combination of poor food and dark or poorly lighted quarters produces a pallor of this type—the so-called prison pallor. Persons who have renal disease also often show a peculiar waxy pallor.

Anemia may be caused either by an excessive destruction or by an insufficient formation of red cells. Thus hemorrhage and

deprivation of iron are both followed by anemia, but from opposite causes. A loss of red cells acts as a stimulus to the red marrow to form new cells at a more rapid rate. Thus frequent hemorrhages, such as from excessive menstruation, bleeding hemorrhoids, or repeated nose-bleed, may be compensated for a long time by an increase in production of red cells. In fact, the production may at times over-compensate the loss of blood. If, however, the hemorrhages are severe or often repeated, the reparative processes become exhausted either from lack of iron or from fundamental changes in the bone marrow.

Many poisonous substances cause a destruction of the red cells of the blood. Lead in various forms and from many sources, likewise benzol and aniline derivatives, when inhaled, swallowed, or absorbed through the skin, are poisons which lead to anemia. Chronic infection from pus pockets around carious teeth may act in a similar manner. The anemia resulting from infection with hookworm is due in part to continual slight hemorrhage and in part to a toxic substance which the parasites secrete.

Chlorosis is the name given to a type of anemia which occurs exclusively in young women. The disease usually develops about the time of puberty. Although those afflicted are pale and show the common symptoms of anemia, they usually appear well nourished. A peculiarity of chlorosis is that the number of red cells in the blood is only slightly diminished; but the amount of hemoglobin in these cells is greatly decreased. An increase in the amount of iron in the food cures the disease. Formerly it was common; now it is rare.

In the common types of anemia the symptoms arise entirely from the lack of hemoglobin in the blood. Such is not the case in the so-called pernicious anemia. This disease is characterized not only by a decrease in the number of red cells, but also by changes in the nervous system which lead to loss of sensation in the hands and feet, difficulty in walking or standing, and paralysis. It has recently been discovered that this serious and heretofore invariably fatal disease can in many cases be cured by feeding the sufferers fresh liver or an extract made from it.

Persons who suffer from anemia are weak, become short of

breath on moderate exertion, and fatigue easily. The amount of oxygen they can consume per minute is decreased. In fact, most of the effects of anemia are immediately due to the oxygen deficiency in the tissues which it produces.

Polycythemia.

An increase above normal in the number of red cells or in the hemoglobin is called polycythemia. An apparent polycythemia is produced when the volume of blood is decreased as in water starvation or Asiatic cholera, and its elements are thus concentrated. A true polycythemia occurs when there is a disturbance in the balance between red cell destruction and formation with the latter in preponderance. The number of red cells may be increased from the normal 5,000,000 to 7,000,000 or 10,000,000 per cubic millimeter; exceptional cases have shown 15,000,000.

In some instances polycythemia is an adaptation of the body to a particular environment, such, for example, as high altitudes where the air is rarefied. When the blood is exposed in the lungs to a decreased pressure of oxygen the concentration of oxygen in the blood is reduced. Under these conditions a compensatory polycythemia gradually develops; with the increased power to carry oxygen the blood is able to absorb the normal amount. In the high Andes red cell counts of 7,000,000 or 8,000,000 per cubic millimeter are normal. The adaptive increase or decrease to change in altitude is not immediate, but develops in the course of a few weeks after change to the new residence. Long exposure to small amounts of carbon monoxide produces a polycythemia in a manner similar to altitude. Blood counts made on men who work about blast furnaces in some instances have shown 7,000,000 or 8,000,000 red cells per cubic millimeter.

Contrary to the claims made for many patent medicines, taking large amounts of iron does not increase the number of red cells in the blood unless anemia exists. Persons who have a polycythemia do not feel exhilarated, nor are they more than usually resistant to fatigue. In the environment which causes

the polycythemia, however, they are able to maintain activities which would be impossible for a person with the red-cell count found at sea-level.

Transfusion of Blood.

The blood of one man may be transferred to the vessels of another man. Such transfusion is performed after serious hemorrhage, also for the treatment of hemophilia or other hemorrhagic disease, and for severe anemia. The red cells of the transfused blood live for only a short time in the new host. They are destroyed in the liver. Except in hemophilia, in which the benefit derived is not from the red cells but from other elements in the blood, transfusion is a measure designed to tide over an emergency and to maintain life until the normal reparative processes have time to operate.

The blood of an animal cannot be transfused into man, for the bloods of different species frequently react so that the red cells lake or clump together and form minute emboli. Likewise in certain instances even human bloods may react in this way. Fortunately, the presence or absence of harmful reaction can be determined before transfusion is carried out by mixing a few drops of the different bloods and examining them under a microscope.

Circulation of the Blood.

The blood is the vehicle for the transportation of substances within the body. It can perform its function only when it is kept in motion. The heart supplies the motive force and the blood vessels form the channels which direct its course.

The heart is a muscular bulb divided longitudinally by a partition into what are virtually two hearts. On relaxation these chambers are distended by an inflow of blood from the veins. When they contract this blood is forced out. An arrangement of check valves directs the stream so that the blood entering from one set of vessels is ejected into another set under increased pressure. In other words, the heart is a pump.

The chambers of the heart which give pressure to the blood stream, and which are guarded by valves, are known as the ven-

tricles of the heart. Above each ventricle is a distensible chamber, an integral part of the heart, in which the blood collects to fill the ventricles. These chambers are known as auricles.

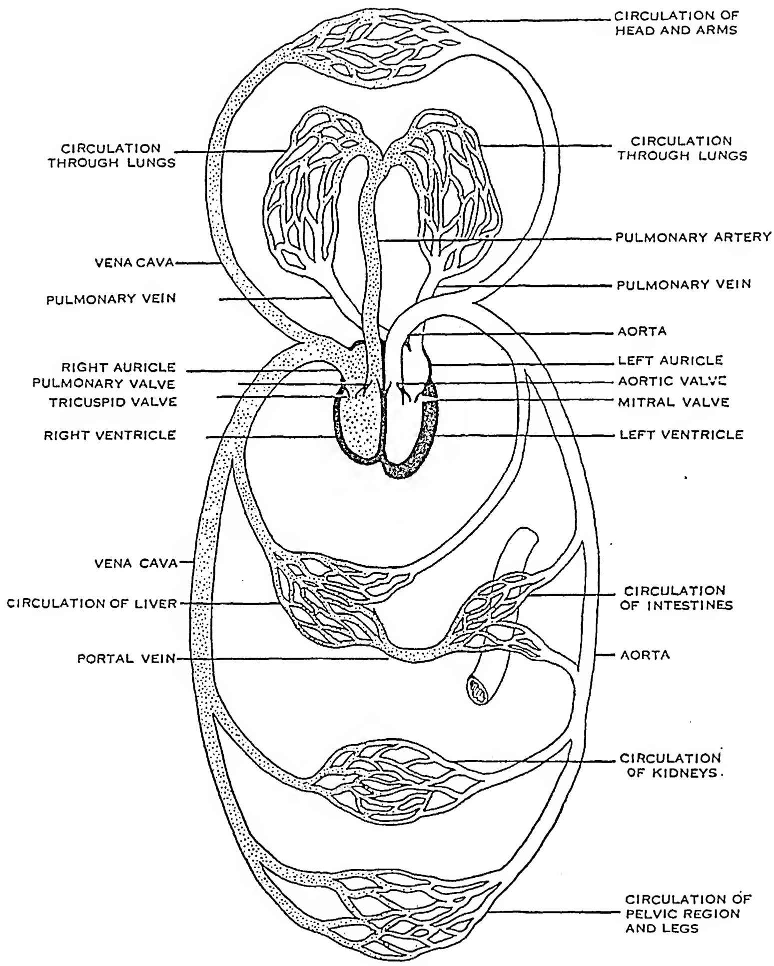

Figure 14. Course of the Circulation.
The shaded area indicates blood in the venous condition.

In the veins the blood flows toward the heart, and the pressure in these vessels is low. In the arteries the blood flows from the heart, and the pressure is high. The arteries form the distributing system for the blood. The veins recollect it and carry it back to the heart. The blood within the veins and arteries

does not come into direct contact with the cells of the tissues of the body. No exchange of substances occurs through their walls. The arteries communicate with the veins through the capillaries. Capillaries are very minute tubes sometimes barely large enough to allow the corpuscles to pass in a single file. The walls of the capillaries are exceedingly thin. An active exchange of material takes place through them between the blood and the cells of the tissues. A closed system is formed by the heart, the arteries, capillaries, and veins. Within these vessels is inclosed all of the blood in the body. Through this system the blood is circulated by the pumping action of the heart.

The course through which the blood moves was first established in 1628 by William Harvey. By two large veins, the venæ cavæ, one from the head and arms, the other from the abdomen and legs, the blood is poured into the right auricle. It flows from there through a valve into the right ventricle. By the contraction of the right ventricle the blood is forced through a second valve into the pulmonary artery, which goes to the lungs. From the pulmonary artery the blood flows through the capillaries of the lungs, and is thus aërated. Leaving the capillaries, it is collected in the pulmonary veins, from which it goes to the left auricle. From the left auricle the blood flows into the left ventricle. From there it is forced into the great artery of the body, the aorta. Arteries branch from the aorta and pass to every part of the body. They terminate in capillaries permeating every tissue. From the capillaries the blood is collected into venules which enter large veins, until the stream is finally gathered into the venæ cavæ. Thus the round of the circulation consists in the blood being pumped by the right side of the heart through the lesser circulation of the lungs to the left side of the heart, and by the left side through the greater circulation to the tissues of the body and back again to the right side of the heart.

Factors Determining Arterial Pressure.

When a large artery is cut the blood escapes under such pressure that if a vertical glass tube is inserted the column will rise to a height of five or six feet. The first experiment to demon-

strate this fact was made in 1732 by Stephen Hales, a preacher, who performed it on a horse. The column in the tube pulsates. This pulsation of the pressure in the arteries can be felt by placing the finger over those arteries which run near to the surface, as in the wrist, neck, or temple. When a vein is cut the blood wells out in a continuous stream under no evident pressure. It does not pulsate. The superficial veins on the back of the hands offer no appreciable resistance to compression when a finger is placed upon them. A pink color is imparted to the skin by the blood which flows through the capillaries; that the pressure of the blood in the capillaries is slight can be made evident from the small force which it is necessary to apply to the surface of a finger nail or on an area of the skin in order to blanch it by driving out the blood of the capillaries.

Structure of Blood Vessels.

The structure of the blood vessels corresponds to their function. The arteries are strong elastic tubes sufficiently firm to hold their shape when they are cut and emptied of blood. The elasticity of the arteries tends to minimize the fluctuations in the blood pressure arising from the intermittent action of the heart. This action is analogous in principle to the air cylinder on a water pump. During the stroke or systole of the heart the larger arteries are stretched by the blood forced into them. During the relaxation of the heart they recoil, converting this potential energy into dynamic energy, and thus spreading the force of the stroke over the time between beats, or diastole.

The veins are of lighter construction than are the arteries. When exposed and emptied of blood they collapse into thin ribbons. The size of a vein is varied by the pressure of the blood within it. This variation is apparent in the veins which run near the skin. Those on the wrist or forearm swell when the blood is dammed back by tightly grasping the arm. The veins in the hand are seen to fill and empty when the hand is held down and then lifted above the shoulder. Most of the veins are equipped with valves placed at irregular intervals. These valves are so arranged that the flow toward the heart is unimpeded, but flow back toward the hands or feet is checked.

The valves thus prevent the blood in the veins from running into branches which may be momentarily at a lower pressure than the main vein. They also make possible an acceleration of the flow of blood through the compressing action of moving muscles. Thus movements of the legs help the return of the venous blood.

The capillaries are so exceedingly minute tubes that many thousand perforate a piece of tissue no larger in diameter than a common pin. They are very short, averaging about 0.5 mm. (0.02 inches) in length. Their diameter, like that of the veins, varies with the pressure of the blood within them. Their walls are made up of a single layer of thin cells. The capillaries permeate the tissues and thus supply the cells.

Regulation of Blood Flow.

The supply of blood to any organ or tissue can be augmented in two ways: (1) by increasing the pressure of the blood in the arteries; and (2) by increasing the caliber of the arteries. The arteries have a layer of muscle fibers in their walls. These muscle fibers are supplied with nerves. Impulses brought by these nerves cause the small arteries or arterioles to constrict; when the impulses cease the arterioles dilate again. The nervous mechanism through which this variation is produced is balanced, so that when one group of vessels relaxes another group is constricted. By this means the resistance to the flow of blood is kept constant so that the general pressure of the blood is maintained. When the arms or legs are exercised the vessels supplying the muscles with blood are dilated; at the same time those to the abdominal organs are constricted. The flow of blood is thus diverted to the exercised part. Violent exercise soon after meals may interfere with the secretion of gastric juice and thus stop digestion. The nerves which go to the arterioles are bilateral in their action, so that when only one arm is exercised the opposite and unexercised arm also receives an extra supply of blood.

The constriction and dilatation of the vessels which supply the skin of the face are often quite apparent. Blushing is caused by the dilatation of the vessels; the pallor which accompanies

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does not come into direct contact with the cells of the tissues of the body. No exchange of substances occurs through their walls. The arteries communicate with the veins through the capillaries. Capillaries are very minute tubes sometimes barely large enough to allow the corpuscles to pass in a single file. The walls of the capillaries are exceedingly thin. An active exchange of material takes place through them between the blood and the cells of the tissues. A closed system is formed by the heart, the arteries, capillaries, and veins. Within these vessels is inclosed all of the blood in the body. Through this system the blood is circulated by the pumping action of the heart.

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fear or other strong emotions is due to constriction. The vessels of the skin also become dilated as a result of exercise or hot surroundings. In consequence of the increased flow of blood the skin becomes warmer; more heat is thus dissipated from the body. A hot bath soon after meals may cause indigestion through the compensatory constriction of the abdominal vessels accompanying the dilatation of the vessels in the skin. Cold tends to cause the vessels in the skin to contract, but exposed parts like the ears may redden because the constrictor nerves are paralyzed by the cold.

If a large number of arterioles are constricted simultaneously while the heart continues to deliver the same amount of blood, the pressure in the main arteries will be increased, because of the greater resistance offered to the flow of blood. As a result, the flow of blood will be increased in those areas where no constriction has taken place. It is in this manner that the blood supply to the brain is regulated. The brain is inclosed in an inelastic shell of bone; the amount of blood within the skull cannot be much increased. By increasing the pressure, however, the velocity of the blood flow through the brain is accelerated so that a greater amount of blood passes through it in a given time. If the brain requires more blood the remainder of the body has to do with less in order that the pressure may be increased by the constriction of the vessels. During mental concentration the blood pressure is raised; the extremities may feel chilly in consequence of the decreased circulation there.

If a number of arterioles dilate simultaneously the blood pressure falls because of the decreased resistance offered to its flow. Sudden emotion at times produces such a dilatation. Fainting may follow in consequence of the decreased blood supply to the brain. The nitrites, such as sodium or amyl nitrite, or nitroglycerine, cause the blood vessels to dilate and the pressure to fall. These drugs are sometimes used to treat high arterial pressure, but more particularly to relieve the spasm of the arteries supplying the heart in the disease angina pectoris.

The flow through the capillaries is largely dependent upon the amount of blood furnished them by the arteries. Occasionally, however, the capillaries remain dilated even when the art-

erioles constrict. The blood in the tissues then becomes stagnant and the hemoglobin reduced. Cold sometimes produces this reaction. The skin, particularly about the lips, then appears blue.

Besides the control of the arterioles exerted through nerves, there is also a chemical regulation of their activity. The internal secretion of the adrenal glands, adrenalin, constricts the vessels, causing the blood pressure to rise. This internal secretion is normally present in the blood; it probably assists in maintaining the arterioles in a state of muscular tenseness or tonus. When the glands are removed or become diseased the blood pressure falls. The rise in blood pressure which accompanies excitement is, in part at least, occasioned by an increase in the secretion of the adrenal glands.

Amount of Blood Pumped by the Heart.

The amount of blood pumped by the heart is an important factor in maintaining the pressure of the blood. A widespread dilation of the vessels may be compensated or more than compensated by an increased output of blood. Thus during muscular exercise the blood pressure rises, although the flow of blood to the exercising parts is increased. The amount of blood pumped by the heart varies with the general need of the body for oxygen. The amount of blood pumped varies more or less with the rate at which the heart beats. This correspondence does not, however, always hold true. When the rate of the pulse is increased from emotion or as a result of drinking coffee or smoking, the flow of blood is not correspondingly increased; the stroke or output at each beat is therefore smaller. A similar condition occurs in fatigue.

The position of the body influences the amount of blood pumped by the heart. In most persons the flow of blood is 15 to 25 per cent greater while sitting than while standing and an additional 15 to 25 per cent greater while lying down. The decrease in the amount of blood pumped in the standing position accounts for the fainting which occurs in men standing rigidly as soldiers do at attention.

When a man of average size is sitting at rest his heart pumps from the left side from 5 to 8 liters of blood each minute and

an equal amount, of course, from the right side, through the lungs to the left heart, making a total of 10 to 16 liters. Under severe exercise the volume pumped per minute may be tripled.

Measurement of Arterial Pressure.

The pressure of the blood in the larger arteries is easily measured. To do so a cuff consisting of a flat rubber bag, loosely covered with cloth, is bound around the upper arm. The cuff is inflated with a hand pump. As the pressure rises in the cuff it compresses the arm with increasing force. A pressure gauge or a mercury manometer indicates the air pressure within the cuff. The observer notes with his finger the pulse of the artery in the wrist of the subject. When the air pressure in the cuff equals, or very slightly exceeds, the pressure of the blood in the artery, the flow of blood is shut off and the pulse is no longer felt. The pressure gauge is then read. The value found is the so-called maximal or systolic pressure. A more precise method of noting the cessation of blood flow is to listen to the sounds within the artery by means of a stethoscope placed at the inner surface of the elbow. No sound is observed in the unobstructed artery, but as the compression of the arm is increased a distinct clicking is heard. This sound arises from the walls of the artery snapping together. The pressure of the blood within the artery is pulsating, rising to its highest during the stroke or systole of the heart and falling to its lowest just before the next stroke takes place. When the pressure within the air cuff equals the minimal pressure reached by the blood in the artery (the diastolic pressure), the artery is opened for a moment as the pressure rises, but when the pressure falls again the walls snap together, giving rise to an audible click with each beat of the heart. As the pressure in the cuff is further increased the clicking sound becomes less distinct. It finally disappears when the pressure in the cuff slightly exceeds the systolic pressure within the artery, for the blood can no longer open it.

Arterial blood pressure is recorded as the systolic and diastolic pressures. From the difference between the measurements is derived the pulse pressure. Systolic means the highest pressure reached during the stroke of the heart. The term blood pressure,

or better arterial pressure, means the systolic pressure. Diastolic pressure is the lowest ebb of the pressure in each pulse wave. It is, in many ways, more important than the systolic, for it is the pressure to which the arteries are exposed at all times; it is the minimum load which the heart must carry in order to maintain the circulation. The pulse pressure is the difference between the systolic and diastolic and expresses the extent of the fluctuation in pressure at each beat of the heart. The term "blood pressure" is commonly used, but it arose from a false conception of the mechanics of the circulation. It should be called "arterial pressure" for it exists only in the arteries.

Variations in Arterial Pressure.

Arterial pressure is observed with the subject in a state of rest and as free from emotion as possible. Excitement, even the excitement of having the arterial pressure test made, causes the pressure to rise. Because of this nervous influence the lowest pressure found in a number of trials is taken as the individual's average pressure. Arterial pressure varies with age. During infancy and childhood the systolic pressure usually ranges between 75 and 90 millimeters of mercury. In young adults it is 100 to 130 millimeters. In old persons 130 to 150 millimeters may be taken as about the normal values. It is often stated that for an adult the blood pressure in millimeters should equal 100 plus the age in years; and such values are commonly found. Nevertheless, at any age a pressure consistently above 150 millimeters during rest without emotional excitement is abnormal.

In a general way the diastolic pressure follows the systolic, running from 30 to 50 millimeters below it. The diastolic pressure rises when the resistance to the flow of blood in the arterioles is increased. If the heart is healthy this increase is compensated by the exertion of a more forceful contraction by the heart. If the heart is not capable of carrying the added load, signs of cardiac fatigue or failure appear, and the size of stroke and with it the pulse pressure are decreased.

Many conditions cause a brief variation in the arterial pressure. Emotion, mental concentration, and worry are accompanied by a rise in the pressure. A rise of 50 per cent has been

observed in a professor while delivering a difficult lecture; and if it is a good lecture and closely followed, it may cause half as great a rise in his auditors. The effect of muscular exercise is variable. Moderate exertion, such as walking, may cause the diastolic pressure to diminish without markedly influencing the systolic, thus increasing the pulse pressure. Severe exertion, on the contrary, tends to increase both the diastolic and systolic. Tobacco and coffee cause a rise of arterial pressure. Hot baths, or high temperature from any cause, tends to diminish the blood pressure. Severe exercise performed under warm surroundings, however, results in arterial pressure higher than a similar exertion performed under cooler surroundings.

On lying down, the arterial pressure normally drops from 10 to 20 millimeters; a rise by a similar amount follows the return to the erect position. The variation in pressure accompanying change in position is due to an alteration in the size of the arterioles, especially in the abdomen. The heightened pressure in the erect position tends to overcome the increased hydrostatic pressure against which the blood to the brain must be pumped. The compensatory response made by the arterioles to change in position is a nervous reaction. It varies in different people and in some may even be reversed; it is not always constant in the same person. To some extent the pressure change is an expression of the state of the nervous system. The momentary period of dizziness, headache, or blindness, which many persons experience in rising suddenly from the recumbent position, is caused by a diminished flow of blood through the brain resulting from a lag in the compensatory reaction of the blood pressure.

Chronic High Arterial Pressure.

A chronic high arterial pressure is common in persons over forty years of age. The immediate cause for this pressure is an increased resistance to the flow of blood in the smaller arteries. The underlying cause of this decrease in the size of these vessels is not known. Presumably, however, it is due to a tightening of the muscles in their walls. These vessels, nevertheless, still retain the capacity to relax and thus regulate the blood flow to

the various organs in a normal manner. They also relax under the influences which normally decrease the arterial pressure, such as amyl nitrite. The tightening of the muscles of the arterioles is similar to the decrease in the elasticity of the muscles throughout the body, which is one of the characteristics of age.

Disease of the kidneys is a common accompaniment of chronic high arterial pressure. During acute kidney disease the arterial pressure rises, presumably from the action of uneliminated waste products, but it falls again with recovery from the disease. High arterial pressure is not invariably accompanied by disease of the kidneys. Nevertheless, an increasing pressure is often the first indication of such chronic disease of the kidneys (see Chapter XI).

Increased arterial pressure increases the work of the heart. The energy expended by the heart in pumping a given quantity of blood is proportional to the pressure against which it must pump it. Increased pressure is much more marked in the systemic circulation than in that through the lungs. Therefore it is the left side of the heart which bears the added burden. The heart, like any other muscle, increases in size when forced for a long time to do an unusual amount of work. Chronic high arterial pressure, therefore, leads in time to an enlargement of the left side of the heart. The pressure in the veins is not increased appreciably even in the aged, unless there is disease of the heart.

Arteriosclerosis.

High arterial pressure as a distinct condition sometimes gives rise to symptoms, but its great importance lies in the fact that it leads directly to hardening of the arteries.

Arteriosclerosis, or hardening of the arteries, is a disease in which the walls of the arteries, particularly the larger ones, become thickened and lose their elasticity. In some cases the condition may be more or less evenly spread over the entire system; in others it is particularly marked in small areas. In extreme cases calcium salts are deposited in the arterial walls so that they become brittle. A normal artery and one which is hardened differ in much the same way as a new rubber tube and one which

has become partially vulcanized from long exposure to the air. Some degree of arteriosclerosis is an almost universal accompaniment of age. Longevity depends in large part upon the length of time which the arteries can hold up against the pressure of the blood. This idea is expressed in the axiom that "a man is as old as his arteries."

Hardening of the arteries depends upon two factors: (1) the quality of the elastic tissue in the walls of the arteries, which the individual has inherited; and (2) the amount of wear and misuse to which this tissue has been subject. Entire families sometimes develop arteriosclerosis at an early age from no apparent cause. This tendency can only be explained on the ground of inheritance of a poor quality of tissue. More commonly arteriosclerosis results from deterioration of once good blood vessels.

High arterial pressure is the most common cause of hardening of the arteries. The strain to which the vessels are exposed, and their consequent tendency to harden, is increased according to the pressure to which they are subjected. Men engaged in occupations which require severe muscular exertion frequently have a high arterial pressure and develop arteriosclerosis at an early age. On the other hand, men who lead a sedentary life, but who are exposed to continual mental strain, and especially to worry, develop a high arterial pressure and hardened arteries. Arteriosclerosis is relatively uncommon in women.

High pressure and hardened arteries are commonly associated. Hardening of the arteries does not in itself cause a high arterial pressure; on the other hand, high arterial pressure may exist for some years before the vessels become affected. The length of time that the vessels can withstand the increased pressure without hardening depends upon the character of the tissue in the vessels. When the change has commenced, however, it usually progresses very rapidly. For this reason it cannot be emphasized too strongly that everyone should, at least once a year, have his arterial pressure determined. Any increase will thus be detected and can be treated before irreparable damage has been done to the vessels.

Arteriosclerosis may result from other factors than high arterial pressure. Changes of this type may result from chronic

lead poisoning and also from acute infection such as typhoid fever, or chronic infections from pus pockets. Gout is also a predisposing factor. Next to high arterial pressure syphilis is probably the most important cause of premature arteriosclerosis.

Consequences of Arteriosclerosis.

Arteriosclerosis may sometimes be borne for many years without noticeable effect. The serious consequences of the disease arise in two ways: (1) the weakened or brittle vessel may break under the strain of the high pressure which is commonly associated with the disease, or (2) the arteries in some areas may be partially obstructed through the thickening of their walls so that the blood supply is restricted. The rupture of a hardened vessel frequently takes place first in the retina of the eye, resulting in partial blindness. Usually it occurs ultimately in the brain; the condition resulting is called apoplexy, or a stroke. The consequences vary from instant death to paralysis, frequently of only one-half of the body. There may be a partial recovery from the paralysis, but usually a second and third attack follow after varying intervals (see Chapter XIV).

The symptoms which accompany partial obstruction to the blood flow depend upon the organ affected. If it occurs in the vessels of the heart, serious damage is done to this organ and its effectiveness as a pump is impaired. In the brain a restricted flow of blood causes various transient or permanent mental and nervous conditions; these may range from a short period of paralysis or aphasia to hopeless insanity. It is probable that many of the mental changes in old age are due to the restricted flow of blood from hardening of the arteries. If the flow of blood to the legs is decreased it may lead to tingling, numbness, or weakness. In rare instances it may occasion what is known as intermittent limping; after a few minutes of walking the muscles of the leg become cramped; locomotion then becomes difficult or impossible until after a period of rest.

Angina Pectoris.

Angina pectoris means pain in the breast; it is the name given to a disease of the arteries which supply the muscle of

the heart itself. A mild form of angina pectoris, called pseudo angina, occurs from the excessive use of tobacco, coffee, or tea. The sharp pain often associated with palpitation soon ceases when the cause is removed. True angina pectoris is an intensely painful and often instantly fatal disease. It is caused by an obstruction to the flow of blood in the vessels which supply the heart. The obstruction usually arises from a hardening of the arteries and restriction of their caliber. The disease is then essentially the same as the intermittent limping described above. In other cases the constriction may be caused by a spasm of the muscles in the walls of the arteries.

Angina pectoris is not a disease of workingmen. It occurs in those who lead a life involving responsibility, mental activity, and worry. It is sometimes called the "business man's disease." Its onset occurs usually after the fiftieth year; although syphilis may cause it in much younger persons. The pain which the disease causes is not constant, but comes in attacks precipitated by emotion or exertion. The famous physician John Hunter, who suffered from this disease, was wont to remark that "his life was in the hands of any rascal who chose to worry him." His fatal attack did occur during a fit of anger.

The attacks of angina pectoris are precipitated by factors which cause the blood pressure to rise; relief follows the return of the pressure to normal. Amyl nitrite, because of its effect in dilating arterioles, is used to treat this disease. At the beginning of an attack a glass capsule of the nitrite is broken in the handkerchief, and the vapor is inhaled.

Aneurism.

When an artery becomes weakened through disease, or is subjected to unusual strain, it may bulge out over part of its length, or give way in one spot and form a sac filled with blood. The enlarged portion is known as an aneurism. The aorta is the artery most commonly affected; next in order is the femoral artery at the point in the leg where it passes behind the knee joint.

The strain of sudden violent muscular exertion may cause

an artery to give way and form an aneurism. Aneurism may also occur in a vessel which has become injured from a wound or a severe blow. Infectious diseases such as typhoid may damage the arteries and lead to the formation of aneurisms; similarly areas in the walls of hardened arteries may give way. The greatest cause of aneurism, particularly that of the aorta, is syphilis. This is especially the case when the infection is associated with a high blood pressure. An aneurism of the aorta may become so large that its pressure erodes the breastbone; a pulsating mass then appears beneath the skin of the chest. The particular danger from aneurism lies in the possibility that the walls of the artery, already stretched and weakened, may rupture, causing a serious or even fatal hemorrhage.

When the aneurism is in the form of a sac projecting from the side of a vessel, it sometimes heals through the clotting of the blood which it contains with the formation of a heavy deposit of fibrin. Aneurism of the aorta cannot be treated surgically, but those in the leg are sometimes removed. In such cases the flow of blood is forced to make a détour about the area through the small communicating arteries. These vessels increase in size so that in time they are able to carry the normal volume of blood.

Varicose Veins.

A vein is said to be varicosed when it has become dilated and lengthened. Because of its lengthening the vein follows a tortuous course. The superficial veins of the leg are most often affected. The veins which follow the spermatic cord into the scrotum may also become varicosed; the irregular enlargement which can then be felt in the sac is known as a varicocele. Hemorrhoids or piles are varicosed veins at the lower end of the rectum and around the anus.

The superficial veins of the leg normally have many check valves, which divide them into segments. The valves permit a flow of blood only in the direction of the heart. Some of these segments are connected by branches to other veins placed deep in the muscles of the leg. The valves of the communicating veins permit the blood to flow from the superficial to the

deep veins. In the groin the two systems unite in a common trunk which joins the vena cava in the abdomen. Every movement of the leg muscles compresses the veins and passes the blood from one segment to the next, while the valves prevent return. When one stands without moving his legs, the blood collects in the veins, until a hydrostatic pressure accumulates sufficient to lift the blood to the heart. Anyone who stands still for a long time experiences the discomfort which arises when the flow of blood is not assisted by the movement of the muscles. The loss of the valves in the veins of the legs results in the veins becoming varicosed. This destruction of the valves is usually brought about by increased abdominal pressure which results from strain, as in lifting heavy objects. The blood in veins within the abdomen is forced back against the valves in those of the legs. The deep veins are reinforced by the muscles about them, but the superficial veins which have no such protection are stretched under the increased pressure and their valves are destroyed.

In the absence of valves the action of the muscles can no longer assist the flow of blood, so that whenever the body is erect, whether the legs are stationary or not, the superficial veins carry a high pressure. Furthermore, the deep and superficial veins are connected both along their course and at the top. The pumping action within the deep veins, which have maintained their valves, draws in the blood from the varicosed veins through the lower communicating channels. At the same time the varicosed veins are kept filled with blood through the junction of the two sets in the groin. A reversal of the blood flow in the outer veins is thus produced, and the blood is recirculated in the leg; congestion follows. Varicosed veins of the leg are readily distinguished from normal veins. The blood can flow down them as well as up. Therefore when the leg is first elevated and then lowered, the veins are immediately filled. In a normal vein, on the contrary, as much time as half a minute is required to fill the leg veins.

Varicose veins of the leg occur in men who do hard physical work, or whose occupation causes them to stand many hours

each day, and more particularly under both conditions. Among women the cause is almost always child-bearing.

The disabling complication of varicose veins is the formation of ulcers. The poor circulation of blood in the leg retards the normal healing process so that slight scratches or bruises lead to open sores which may persist for many years. In extreme cases among persons with uncleanly habits, flies may lay their eggs in the unhealthy flesh which becomes riddled with maggots. Another and dangerous complication of varicose veins is thrombosis and inflammation, phlebitis. The stagnation of the blood flow is the predisposing factor to the formation of the clot. Varicose veins of the leg are treated either by surgical removal or through the wearing of supporting stockings or bandages.

Hemorrhoids.

The veins of the rectum have no valves and varicosity in them is caused by simple dilatation. Like the superficial veins of the leg, they are held in a loose tissue, so that they lack support. If the pressure of the blood within them is markedly increased they may be stretched. The pressure of the blood in a vein is low only so long as the flow is unobstructed. When the vein is blocked the pressure in it gradually rises until it equals that in the artery which supplies it. The act of defecation, particularly if it is difficult or prolonged, increases the pressure within the veins of the rectum. Chronic constipation is, therefore, a predisposing factor to hemorrhoids. Hemorrhoids are common in young persons, especially men of about twenty years who lead a sedentary life. Young women are usually quite free from the condition, although it may occur after pregnancy.

Hemorrhoids are often present without the individual being aware of it. The condition may be brought into prominence, popularly called an "attack of piles," through the occurrence of thrombosis in the vessels. The thrombosis is frequently brought on by the use of violent purgatives or by local exposure to damp or cold, as by sitting on a cold wet stone.

Piles are spoken of as external and internal. The external variety project through the anus as dark brown folds of skin.

They usually give rise to no discomfort beyond some itching and perhaps slight irritation immediately before and after defecation. When thrombosis occurs within them they appear as swellings of bluish color which are painful and tender, often preventing the sufferer from sitting or walking in comfort. If further irritation is prevented the inflammation usually subsides after a few days or can be relieved by removing the blood clot by surgical operation. Internal piles are covered with the mucous membrane which lines the rectum. At first they are held above the anus. Later, however, they tend to protrude. This type of hemorrhoid is very prone to bleed. The persistent hemorrhage may even lead to anemia. Internal piles usually cause much more discomfort than the external type, but are less liable to inflammation. Internal piles may be benefited by relieving constipation and improving the general health. If pain and bleeding persist the dilated veins must be removed by surgical operation.

Birthmarks.

A birthmark is formed by a group of dilated capillaries massed near the skin. The commonest type is quite small, rarely over an inch or two in diameter, and is raised slightly above the surrounding skin. They usually occur about the head and face. The "port wine" stain, a less common form, consists of a fine network of vessels. It does not project above the skin but frequently covers a large area involving at times one-half the face. Birthmarks develop before or soon after the child is born. Contrary to an ancient superstition, their formation has nothing whatever to do with the mental state, health of the mother or any accidents prior to the birth of the child (see Chapter XXII).

CHAPTER VII

THE HEART AND ITS DISORDERS
ALSO
THE LYMPHATIC SYSTEM

Position of the Heart.

When the chest is opened by removing the ribs, the heart is seen as a somewhat conical-shaped organ with the base uppermost and to the right, and with the apex projecting down and to the left. In consequence of its oblique position about two-thirds of the heart lies to the left and one-third to the right of the mid-line of the body. The heart varies in size in different persons; the approximate length is 12.5 to 15 centimeters (5 to 6 inches) and the breadth at the base is 7.5 to 10 centimeters (3 to 4 inches). The approximate weight is 270 to 360 grams (½ to ¾ pound). When contracted in systole it is the size and general shape of the left fist held over the chest.

Pericardium.

The heart is enclosed in a double-walled sac of thin tissue called the pericardium, meaning "about the heart." This sac is similar in structure and appearance to the peritoneum which covers the intestines and abdominal cavity. The pericardial sac fills most of the space between the two lungs and is attached below to the diaphragm. The closed top of the sac turns in to surround the heart; the arrangement is much the same as if the clenched fist, representing the heart, were pushing in the top of a closed bag. The part of the pericardium which is thus turned in is attached to the heart. The outer layer is loose, and the space between the two layers has in it a small quantity of fluid. During the movements of the heart the smooth inner surfaces of the two layers of the pericardium rub together. Inflammation of the pericardial sac as a result of infection is called pericarditis; the sac may then become filled with fluid or pus and the movements of the heart impeded. (See Figure 23.)

Structure of the Heart.

As pointed out in the previous chapter, the heart is a pump. In structure it is a muscular bulb divided by a partition into two auricles and two ventricles. It is thus not one, but two, pumps. The walls of the auricles are thin, for these chambers, together with the veins which supply them, serve largely as passive reser-

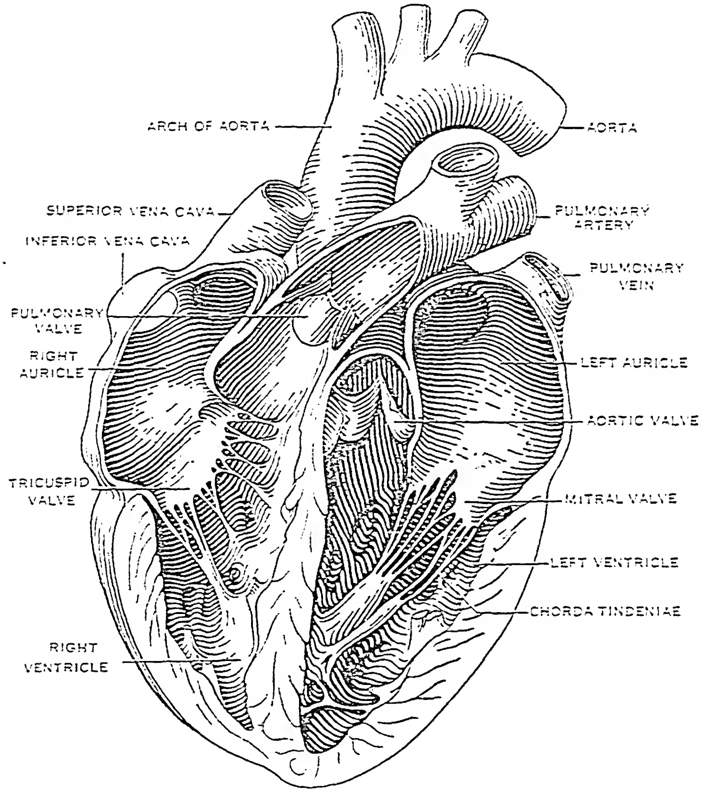

Figure 15. Longitudinal Section of Heart.

voirs in which blood accumulates during the stroke of the ventricles, and from which the blood empties into the ventricles during their relaxation. There are no valves separating the auricles from the veins. The muscular walls of the ventricles are thick, for it is these chambers which force the blood under pressure into the arteries.

Between the auricles and their corresponding ventricles there

are check valves which allow the blood to flow into the ventricle but prevent its return. The valve separating the right auricle and ventricle is called the tricuspid; that separating the left auricle and ventricle the mitral valve. The orifice for each valve is formed by a strong fibrous ring connected on its periphery to the walls of the heart. The valves are formed by a sleeve of thin, flexible but very strong tissue attached to the sides of the orifice. When the valve is open this sleeve extends into the ventricle. The sleeve of the mitral valve is split longitudinally in two places, and the tricuspid in three. Strong fibers

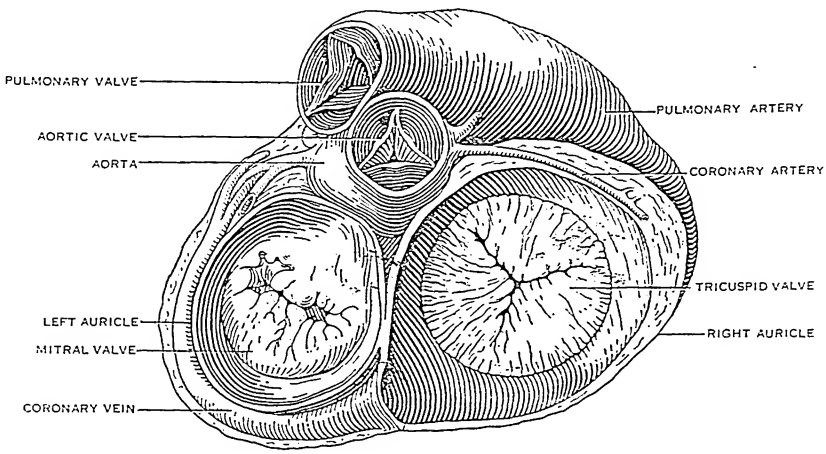

Figure 16. Cross Section of Heart.
Section made through the auricles.

or cords attach the under surface of the valve to the walls of the ventricle, serving as checks to prevent the valves from being forced back into the auricles under the pressure of the blood in the contracting ventricles.

The valves which close the opening between the ventricles and the arteries into which they eject their blood are called semilunar. They are also named for the corresponding arteries the pulmonic and the aortic. Each of these valves is formed of three triangular, or semilunar, folds of tissue. The base of each fold is attached to the ring of connective tissue at the orifice of the valve. The apex of each triangular fold has a small bead or thickening at the point where the three folds meet when closed.

Heart Sounds.

When the ear is placed against the chest wall over the heart, definite sounds are heard. They are produced by the activity of the heart. There is first a dull, long-drawn-out sound which is immediately followed by a second which is short and sharp. A pause then occurs, after which the cycle of sound is repeated. The normal heart sounds resemble the words "l-u-b dub," pause, "l-u-b dub," pause, and so on. The first heart sound arises largely from the tension of the muscle of the ventricle. (Any contracting muscle gives rise to a slight sound, as may be illustrated by putting one's fingers into one's ears and contracting the muscles of the arms or jaws.) The second heart sound occurs at the moment the ventricle finishes its stroke and is caused by the closing of the pulmonic and aortic valves. Occasionally a faint third sound can be heard.

Great importance is attached to the heart sounds in the diagnosis of disease. When a valve leaks, the escaping blood produces additional sounds known as "murmurs." By determining the time relation between the murmur and the normal heart sounds deductions can be made as to which of the valves is affected. The presence of murmurs does not always signify a diseased heart. These abnormal sounds may occur temporarily during anemia and in other conditions in which the heart valves are unaffected. Heart murmurs are significant only when they are associated with other signs of heart disease such as enlargement of the heart, or when there is reason to suspect that the heart is involved in infections such as inflammatory rheumatism.

Work Done by the Heart.

The work done by the heart in circulating the blood depends upon the volume of blood pumped in a given time and the pressure against which it must be forced. For a man at rest about 5 to 8 liters or kilos (approximately 10 to 16 pounds) of blood pass through the left ventricle each minute. As we have seen (Chapter VI), the pressure in the arteries is approximately that of a column of water six feet high—*i.e.,* 128 millimeters of mercury. Therefore, in each minute 10 to 16 pounds of blood are raised 6 feet, and from 60 to 96 foot pounds of work are

done. Sixty foot pounds a minute come to 3,600 foot pounds an hour, or 86,400 foot pounds in twenty-four hours. The left heart of a man who is at rest thus does a minimum daily work equivalent to lifting the man through a vertical distance of over five hundred feet.

With a uniform output of blood the work done by the heart varies in proportion to the pressure against which the blood must be pumped. Therefore, in chronic high arterial pressure the heart is forced to do more work to circulate the blood than when the pressure is normal. During exercise the volume of blood pumped may be three or more times as great as in the resting state and the blood pressure may rise 50 per cent or more. The work of the heart may thus be increased fivefold.

Size of the Heart.

Other things being equal, large individuals have bigger hearts than small individuals; but the heart is correlated with the muscular development of the individual rather than mere weight. The heart is a muscle and, like any muscle—the biceps, for example—its development depends upon the amount of work which it performs. Since the work of the heart is performed by the ventricles, they enlarge as the result of exercise; that is, they "hypertrophy." Thus an athlete may develop a large heart. If only one of the ventricles bears the added burden, as occurs in diseases, then it alone grows larger; in consequence the heart has a right- or left-sided hypertrophy. Chronic high arterial pressure affects the left side, and eventually the left ventricle enlarges. The apex of the heart instead of being about three inches from the mid-line may be moved out to four or five inches. Similarly, enlargement of one side of the heart, particularly the left side, may occur when the pumping action of the heart is impaired by disease and injury, leaking or obstruction of the valves.

Athletic Heart.

Wild rabbits have a larger heart than do caged rabbits who lead a sedentary life. Racehorses and running dogs also have relatively large hearts. A similar enlargement may occur in

men whose occupations involve prolonged violent exertion. The hypertrophy of the heart enables it to do a greater maximum of work and therefore permits the individual to sustain greater exertion. What effect this type of enlargement of the heart may have in the after life of those who subsequently adopt sedentary habits has not been satisfactorily determined. The hypertrophy is of no benefit after the change of habits, and it is possible that the muscles may soften and become more than normally susceptible to disease. There is a belief, although unproved, that for this reason athletes die at a comparatively early age. A more probable explanation, if indeed the condition exists, is that most athletes are so abundantly supplied with health and energy that they are extravagant with these gifts and do not take proper care of themselves.

Dilatation of the Heart.

When the chambers of the heart are abnormally increased in capacity and cannot contract completely, the term dilatation is applied. Dilatation may come on suddenly as the result of a strain which stretches the walls of the heart. The walls of the chambers are then thin and weak. Such dilatation occurs in hearts in which the muscle has become weakened and which, therefore, cannot withstand the strain of violent exertion. A serious dilatation rarely, if ever, occurs in a normal heart in consequence of even the most violent exertion. The muscle of the heart, like other muscles of the body, is temporarily weakened by debilitating diseases such as typhoid fever or influenza. Diphtheria is particularly harmful in this respect. Anemia, lack of food or exercise, or any condition which is detrimental to the general health, also has its weakening effect upon the muscle of the heart. The heart is sometimes weakened by fat which is deposited in the muscle, or it may be weakened by a hardening of the blood vessels, called the coronary arteries, which supply the muscle of the heart, so that it does not receive its normal supply of blood.

What is known as "heart strain" is acute dilatation. When a man in poor condition makes an exertion and thus calls upon his heart for extra work, as during the ascent of a mountain or

running to catch a train or car, he may have a sharp pain in his chest and become very short of breath. The pain and breathlessness usually disappear in the course of a few hours, but when exertion is again attempted they reappear. Such a man may be unfit for any severe exertion for months; he may even be permanently incapacitated. He has strained his heart, which cannot now respond to demands for increased circulation.

Disease of the Heart Valves.

The valves of the heart play a part in its operation like those of any mechanical pump. But they are also living structures and subject to diseases which may prevent them from functioning normally. There are two types of such disorders. The first is a narrowing of the valve orifice, called stenosis, which interferes with the free passage of blood. The second type of disorder is a failure of the valve to close properly, so that blood leaks back through the closed valve. The leak or "incompetence" may be caused by either an erosion, a shortening, or a distortion of the segments of the valve, or it may result from a widening of the orifice to which the valve segments are attached. Stenosis and leakage are usually associated, although either type of disorder may occur singly.

Ninety per cent of the defects of the heart valves occur in those of the left side, the mitral and aortic valves. This side of the heart supplies the general circulation of the body and does the greater amount of work, so that it is associated with the greater liability to strain. The main cause of valvular disease of the heart is an inflammation on the inner surface of the heart, or endocarditis. In acute endocarditis caused by bacterial infection the valve segments may develop open sores or have small wart-like growths on their surfaces. Portions of the valve may be eroded. During healing, raw surfaces of adjoining segments may grow together or, as a result of scars, the valves may be puckered out of shape.

Endocarditis usually results from some other disease such as tonsilitis, scarlet fever, or rheumatic fever. The endocarditis may be relatively mild, occurring as a complication of the primary disease, or it may be of such severity as completely to over-

shadow the original source of infection. Acute rheumatism of the joints, which is common in children, is particularly prone to cause endocarditis. Even mild cases of this form of rheumatism, often erroneously called "growing pains," may be followed by endocarditis. The entry for the bacteria which cause the rheumatism and endocarditis is commonly the teeth and tonsils. Acute endocarditis most frequently affects the mitral valves.

Besides the acute endocarditis caused by infection there is a chronic type which progresses slowly. This condition is similar to hardening of the arteries. The aortic valve is the one generally affected. The segments of the valve become thick and stiff and are drawn out of shape, so that blood leaks through when the valve is closed. Any factor predisposing to arteriosclerosis, such as lead poisoning or syphilis, contributes to this form of endocarditis. Alcohol may also be an accessory factor, although it does not generally have any influence in hardening of the arteries. Leakage of the aortic valve occurs oftenest in men who have been robust and able-bodied and who have done heavy work.

Effects of Disease of the Heart Valves.

Incompetence (leak) and stenosis (constriction) of the various heart valves cause characteristic changes in the circulation of the blood of essentially the same sort as would occur in the pumping of fluid by any mechanical pump similarly deranged. In the body, however, the abnormal circulation itself becomes a cause of further disturbance. Not only the heart, but also blood vessels and the organs themselves may be altered in parts of the body remote from the heart.

When the mitral valve leaks, the blood pumped by the left ventricle passes not only into the aorta, as it normally should, but a portion goes back into the left auricle as well. In order to pump the normal amount of blood to the general circulation, the left heart is forced to pump again the fraction which has leaked. An additional burden is thus placed upon the heart. The left ventricle slowly dilates and the muscle thickens just as the normal heart would when exposed to a chronic high arterial pressure or heavy bodily labor. Since the left side of

the heart thus pumps less efficiently than the undamaged right side, blood tends to dam back in the pulmonary vessels. This results in congestion of the circulation in the lungs.

When the opening of the mitral valve is narrowed, that is, stenosed, the passage of blood from the left auricle to the left ventricle is impeded. As in mitral leakage, but for an opposite reason, the blood is dammed back in the lungs, and extra work is thus thrown on the right side of the heart. If the right heart also fails the resistance offered to the flow of blood from the veins of the general circulation is increased. In mitral stenosis the left ventricle, receiving less blood than normally, does not hypertrophy; it may even become smaller.

Incompetence of the aortic valve allows a portion of the blood pumped out by the contraction of the left ventricle to leak back during its relaxation. As in mitral incompetence, the ventricle is forced to pump an added quantity of blood; the burden thus imposed results in slow dilatation and hypertrophy. From this condition the heart may be tremendously enlarged; weights as high as three pounds have been recorded, four times the normal weight. The most striking change in the circulation in incompetence of the aortic valve is the increase in the fluctuation of the blood pressure at each beat of the heart. As a result of the leaking of blood back into the ventricle the pressure in the arteries falls off very rapidly during diastole; during systole the pressure rises to a normal height or even above. The wide fluctuation of the blood pressure causes the pulse to strike forcibly against the finger placed over an artery. The huge pulse may extend into the capillaries, causing the skin to alternately blush and pale with each beat of the heart. This "water hammer pulse" throws a strain upon the walls of the arteries which results in their hardening rapidly.

Compensation and Its Failure.

By hypertrophy the heart tends to compensate for the added burden which it must carry in valvular disease. The heart of a normal man is able to supply a flow of blood sufficient for violent exertion; during rest or moderate exertion the heart has a large reserve force. When the heart is damaged by disease

of the valves, this reserve force is brought into use even in rest and is thus encroached upon. A heart with a leaking valve in a man sitting at rest may be doing as much work as would a normal heart under moderate or even violent exertion. So long as the reserve force and the changes in the heart itself are sufficient to maintain an adequate circulation, the diseased heart is said to be compensated. No particular ill effects arise from such disease until the compensation fails. But sooner or later this is liable to happen. The most common cause of failure of compensation is the additional demand made upon the heart by bodily exertion. Since the reserve force is diminished by the disease, the limit of the heart's ability to pump blood is reached with less exertion than for the normal heart. If the damage to the valves is progressive, a time may be reached when the entire reserve force of the heart is required for its action even in bodily rest. Beyond this point the heart, although doing its maximum of work, is no longer able to supply a normal circulation, even when the man is at rest.

Shortness of breath after a moderate exertion, such as walking up a flight of stairs, is usually one of the first symptoms of valvular heart disease. An increase in the volume of air breathed after exertion is normal; but panting and shortness of breath only come after vigorous exertion. Breathlessness is to a large extent dependent upon inability of the heart to increase the flow of blood, and its transportation of oxygen, in proportion to the muscular exertion of the body. A man with valvular disease responds to mild exertion as a normal man would to vigorous exertion. In severe valvular disease breathlessness resembling asthma may occur without any particular exertion. In still more severe cases the breathlessness is continuous; it is aggravated by lying down. Such persons are forced to sleep sitting up.

The inefficiency of the heart results in damming back the blood in the veins, so that the pressure in these vessels rises and they show prominently, especially in the neck. The swelling of the legs, which results from the failing circulation and increased venous pressure of severe valvular disease, as well

as from some kidney disease, is known as dropsy. Dropsy consists in the collection of fluid in the tissue spaces—edema. The passage of fluid into these spaces from the blood exceeds the rate of removal by the blood and lymphatics. The fluid tends to accumulate in the more dependent portions of the body, since the pressure in the veins is greatest there.

Death may occur suddenly in valvular disease of the heart, either through a rapid increase in the severity of the condition, as when one of the valves suddenly leaks badly or when the compensation fails. A sudden failure of compensation is called a "heart attack." The most common cause is emotion or excitement or some unusual exertion.

Cause of the Heartbeats.

The heart is to a large extent a self-contained mechanism. Even when the heart is removed from the body, if it is kept warm and supplied with a nutrient and oxygenated fluid, it continues to beat; it will pump the fluid. The power of rhythmic contraction by which it pumps blood is, therefore, intrinsic in the heart. The heart depends upon the remainder of the body only for food and warmth, and for the controlling influences which govern the rate of its beat.

The muscle of the heart has the properties common to all muscle; that is, it will contract when some external force stimulates it. Unlike most other muscle, however, that of the heart has the property of initiating contraction spontaneously and rhythmically; it is automatic. Even a piece of muscle separated from the heart will continue to beat although it receives no stimulation from the outside. Within the heart muscle a cyclic process occurs; products of some nature accumulate until finally a point is reached when this internal stimulation induces a contraction. For a brief period—a fraction of a second—after its contraction the heart muscle is unable to contract again, even though it is stimulated from the outside. Its ability to respond soon returns. When one group of the minute fibers which make up the heart muscle contracts it stimulates its neighbors, and they in turn stimulate others, so that the entire organ contracts, nearly simultaneously. Thus a contraction which has been in-

itiated in any region of the ventricle or auricle is conducted to adjoining regions and tends to produce a nearly simultaneous contraction of the whole ventricle or auricle.

Although any portion of the heart muscle is inherently capable of thus initiating contractions, the pace of the whole heart is ordinarily governed by a single region in which the automatic rhythm is more rapid than in other parts of the heart. This specialized region, or pacemaker, is located in the wall of the right auricle at the point where the venæ cavæ enter. The impulses which arise there cause the auricle to contract, but impulses do not pass directly from the muscle of the auricle to that of the ventricle. To effect this crossing for the impulse there is a relay station located in the wall of the heart at the point where the auricles and ventricles join. This relay or bridge, the so-called "bundle of His," is a small area of specialized tissue which branches down the ventricles. The muscle of the ventricles contracts in response to impulses coming from this relay, which in turn receives these impulses from the contracting auricle. Although the contraction of both auricles and of both ventricles, when an impulse is initiated in either region, is simultaneous, there is a short delay in the passage of the impulse from the auricles to the ventricles, so that the contraction of the former is completed before that of the ventricle has commenced.

Regulation of the Heart Rate.

Variation in the rate of the heartbeat is brought about by the action of two distinct sets of nerves. The impulses carried by these nerves act largely upon the pacemaker of the auricle, modifying the rate at which it sends out its impulses to the muscle of the heart. The action of the two sets of nerves is antagonistic; one slows the rate of beat and the other quickens it, so that the rate at any time is a resultant of the two influences. The nerves which retard the rate are the stronger of the two sets and exert a more immediate influence. These nerves are the vagi, which start from the brain and run down each side of the neck directly behind the carotid arteries. These arteries can be felt, one on each side of the neck, when the finger tips are pressed into the space just behind the windpipe. Impulses are sent down the vagus nerves

continually. When these impulses are increased, the rate of the heart is slowed; when they are decreased, with the antagonistic nerves still active, the rate is accelerated. When both the vagus nerves are cut, the rate of the heart increases greatly; stimulation of the nerve on the side of the cut toward the heart causes the heart to beat slowly or even to stop for a short time. In a normal man a slowing of the rate may be caused by pressing firmly with the fingers on the vagus nerves in their course down the neck. The vagus nerves send branches to the lungs, stomach, and intestines as well as to the heart. When the intestines or stomach are struck nerve impulses are sent to the vagus center, and through a reflex the heart may be influenced. Thus a severe blow on the abdomen may cause the heart to slow down to such an extent that unconsciousness is produced. One of the "knock-out" blows used by pugilists is that to the pit of the stomach; the even more effective "blow below the belt" is forbidden.

The Electrocardiogram.

The energy of the impulses, which arise in the pacemaker, travel over the heart muscle and cause it to contract, is expended in part as electrical energy. By means of a delicate galvanometer this electrical impulse can be detected and recorded. The apparatus used is known as an "electrocardiograph." Electrodes dipped in salt water placed on the hands and feet of the subject are connected by wires to a string galvanometer. This instrument consists of a very powerful magnet with the poles shaped like knife edges and brought nearly into apposition. Between the poles is stretched a thread of quartz so fine as to be almost invisible. The thread is plated with gold to make it a conductor of electricity. The minute current from the heart passing through the "string" deflects it in the magnetic field. A beam of light from a powerful electric lamp casts the shadow of the string through a microscope by which it is magnified upon a moving photographic film. The photographs thus taken are records of the rate, path, and force of the conduction of the impulse of contraction through the heart. This method is used as a means of determining the nature and location of irregularities in the action of the heart.

Pulse and Its Rate.

Irregularity in the rate of the heartbeat appears also in the pulsation which is felt when the finger is placed over an artery near to the surface of the body. The artery commonly examined is the radial, which runs over the under surface of the wrist on the same side as the thumb. The index finger is used to feel the pulse, never the thumb, for it has a small artery near its tip which on pressing the surface may sometimes be felt and mistaken for the pulse to be examined. A graphic record can be taken of the pulse by an instrument which presses on the artery, and through a system of levers transmits its movements, in magnified form, to a pen writing on a revolving drum covered with a strip of paper.

The pulse in an artery is a wave which passes over the blood in the vessel. This wave, a sudden increase in pressure and velocity of the blood in the arterial system, is caused by the contraction of the heart. The pulse wave moves at a much greater velocity than does the flow of blood in the vessels. A similar movement may be caused in a stream of water when a stone is thrown in; the wave formed may travel at a greater rate than the flow of the water downstream. The velocity of the blood in the larger arteries is about half a meter a second; the pulse wave goes some twenty meters in the same time. The pulses felt in the vessels at different distances from the heart are, therefore, not synchronous. By placing a finger of one hand over the pulse of the opposite wrist and at the same time pressing a finger of the latter hand against the carotid artery in the neck, a distinct lag can be detected in the pulse of the wrist.

The average rate of the heartbeat in healthy adults at rest is about seventy beats per minute for men and eighty for women. The rate is much faster in infants, about 130 per minute, but it diminishes during childhood. In old age the rate may again increase. Individuals who are normal may show considerable variation from the average pulse rate. In some it may be 50 or 60; in others a rate as high as 90 per minute may continue even when such accelerating influences as emotion, exercise, coffee, and tobacco are eliminated.

Exercise causes a prompt increase in the pulse rate, for an in-

creased circulation is needed to bring an abundance of blood to the working muscles. The pulse rate may rise to 170 or 180 beats per minute; higher rates are less effective in pumping the blood, for the heart does not have time to fill during diastole. Rates of 200 beats per minute, or even higher rates, occur in untrained men (especially those who smoke much) during vigorous exertion and in severe fatigue. After exercise, the increased rate does not for a time return to normal; the time depends upon the physical state of the person; the sooner it returns the better. When the emotions are aroused the rate of the heart beat is increased, although no greater supply of blood is needed by the body; the acceleration may be considered as a sort of anticipation of the muscular exertions which frequently accompany emotions such as fear and anger; similar anticipatory changes occur in the mobilization of sugar within the body. When the temperature of the body rises above normal, as in fever, the pulse rate is also increased. Thus an accelerated pulse is one of the signs of fever.

Certain factors tend to slow the pulse rate. A heart enlarged by the practice of athletics, but with its action otherwise normal, beats slowly when the body is at rest. The large heart pumps at each stroke a greater amount of blood than the average heart, so that to supply the same circulation the rate can be slower.

The heart may be slowed as a result of injury causing fracture of the skull. When the pressure within the skull, and hence upon the brain, is increased the heartbeat is usually slowed through the stimulation of the vagus nerves. The increased pressure in fracture of the skull results from rupture of a blood vessel and a hemorrhage about the brain. The operation of trephining, boring a hole in the skull, is performed to relieve the pressure. In some fractures of the skull the hemorrhage escapes through the break in the bone and bleeding occurs at the ears or nose. It is unwise to attempt to stop this type of hemorrhage, for its continuation prevents an accumulation of the blood within the skull.

Irregularities in the Heartbeat.

The strength of control of the vagus nerves regulating the rate of the heart may fluctuate. Irregularity in the rhythm of beating is thus produced, although the heart itself may be perfectly nor-

mal. This type of irregularity occurs commonly in healthy children. The fluctuations follow the breathing; during inspiration the rate becomes more rapid, but slows down during expiration. With each breath the cycle is repeated. In this type of arrhythmia the nervous impulses from the lungs reflexly influence the vagus center causing the cyclic changes in the heart rate.

The nerves to the heart may modify the rate at which it beats, but they do not affect the mechanism of the beat. The nerves slow or speed up the rate, according to their influence upon the pacemaker. Disturbances may, however, arise in the conduction of the impulse through the heart muscle, so that irregularities appear not only in the rate, but in the mechanism of the beat as well. The most common disturbance of this type is the so-called premature beat or extrasystole. An extrasystole is a beat which interrupts an otherwise regular heart action by occurring prematurely. When the pulse of a person in whom extrasystoles occur is felt, an occasional pause is noted, followed by forceful impulse. Two beats close together precede the pause; the second of these beats is weak because the heart has not had time to fill properly. The beat after the pause is forceful because the heart has filled to an unusual extent. Most premature beats of the heart originate from some part of the heart other than the normal pacemaker. Although the pacemaker controls most of the action now and again, some other area momentarily rises to a sufficient degree of excitability to act spontaneously, and in so doing sets off the train of contraction in the ventricle. The impulses arising from the pacemaker continue in normal timing, but for a brief period after a contraction the heart muscle is incapable of responding to stimulation—it has a refractory period. The impulse from the pacemaker falls upon this refractory period, the normal beat is omitted, and a relatively long pause occurs. The extrasystole causes no more than the normal number of beats at any time, for while one, a weak premature contraction is gained another is lost.

Extrasystoles are abnormal; their presence indicates the action of some disturbing influence upon the muscle of the heart. They are not an alarming condition, for they may be produced by many factors, some of which are temporary. Tobacco and coffee in excess are common causes; nicotine and caffein both affect the

heart muscle. The action of either substance seems to be heightened by lack of sleep, nervous strain, or dissipation. Extrasystoles frequently occur in diseases of the heart muscle and in chronic high arterial pressure; but they are not indicative of these conditions.

Heart Block.

In the condition called heart block the relay between the auricles and ventricles becomes damaged, so that the transmission of impulses is interfered with or abolished. In complete heart block the relay ceases to function. The auricle beats in a normal manner under the control of the pacemaker, but these impulses are not transmitted through to the ventricle. The ventricle, therefore, drops its rhythm to the spontaneous contraction rate intrinsic in its muscle. This rate is thirty to thirty-five per minute. Exercise, or any other factor which affects the rate of the pacemaker, ceases to have any influence upon the rate at which the ventricle contracts. The heart makes no response to the varying needs of the body for blood. Persons with complete heart block faint when they attempt to perform an exertion, for the extra blood flow to the muscle robs the brain of its supply. Such persons are unfit for any employment except the most sedentary. A common, although not invariable, cause of this disease is a syphilitic growth upon the heart muscle at the junction of the auricle and ventricle. In many instances heart block is incomplete, so that impulses from the auricle are passed, but only in an imperfect manner.

Action of Electricity Upon the Heart.

When the auricle of the heart is stimulated by a strong electric current, the normal sequence of events is altered. The auricle no longer follows the timing of the pacemaker, but each cell, or small group of cells, contracts independently. The whole surface of the auricle twitches and quivers as if stirred by the many centers of independent contractions. The auricle then is said to fibrillate. Fibrillation of the auricle may occur from causes other than electric shock. It is not immediately fatal and constitutes a definite disease. Persons in whom the auricle of the heart fibrillates show a completely irregular pulse. The ventricle cannot then

respond to all of the impulses which originate in the auricle. Most of these impulses stop at the junction of the auricles and ventricles. Some of the impulses which do cross reach the ventricle during its refractory period. Thus the stimulation of the ventricles becomes a matter of chance and many of its irregular beats are premature and too weak to pump much blood. An electric current applied to the ventricle may cause it to fibrillate in a manner similar to the auricle. Since the fibrillating ventricle merely quivers and does not contract, no blood is pumped into the arteries. Death is immediate and no means of resuscitation are of benefit. Sudden death may occur in this manner from an electric shock accidentally received through the surface of the body and running in such direction as to pass near the heart, that is from hand to hand or particularly from a hand to the feet.

The Lymphatic System.

The cells of a tissue do not form a compact mass. Between them there are irregular spaces filled with a colorless tissue fluid; it is in this medium, the lymph, that the cells of the body live. Foodstuffs and oxygen diffuse from the blood through the walls of the capillaries into the lymph. From the lymph these materials are taken up by the cells. In return the waste substances from the cells pass into the fluid around them and so diffuse into the blood.

The lymph is continually renewed by the passage of fluid from and into the blood stream. Water, salts, and dissolved gases can pass through the walls of the capillaries, but proteins cannot. In the first portion of these vessels the pressure of the blood is greater than the osmotic pressure of the proteins which it contains. Therefore fluid passes out. In the final portion of the capillaries the pressure relations are reversed and fluid flows back into the vessels. The outward flow of fluid from the blood in the capillaries is usually slightly greater than the absorption.

The excess of tissue fluid is removed by a system of vessels distinct from those through which the blood circulates. These vessels are called lymphatics. They are minute, thin-walled vessels which ramify through the tissues. They unite finally in a common trunk, the thoracic duct, which passes up through the

chest and empties into the veins near the heart. The flow of lymph is brought about by the pumping action of moving muscles. Whether or not the terminals of the lymphatics open into the spaces between the cells to allow free entrance of tissue fluid, or are closed and only allow diffusion between the lymph vessels and

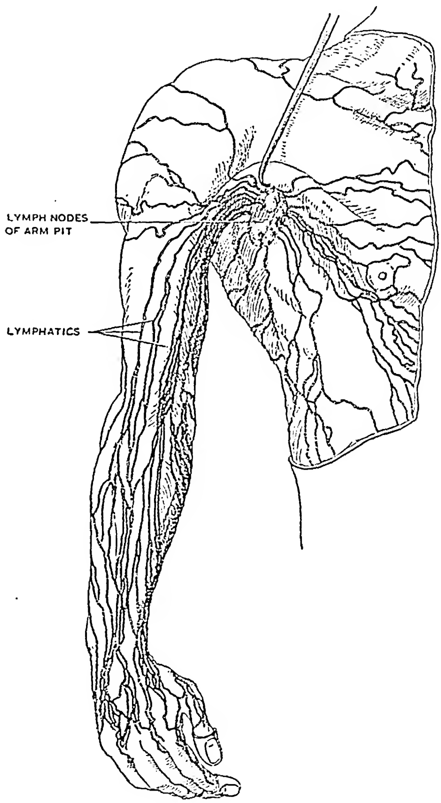

Figure 17. LYMPHATICS OF THE ARM AND CHEST.
The hook shown draws back the muscle to expose the lymph nodes of the arm pit into which the lymphatics of the arm and chest empty.

tissue fluid, is a debated question. Solutions which are injected into the tissue fluid are taken up more rapidly by the blood than by the lymph, but solid particles similarly injected go only into the lymphatics. It may be that solid particles pass into open lymphatics or they may be carried through their walls by white blood corpuscles.

This difference in modes of absorption of fluids and solids from the tissue spaces has extreme importance. Bacteria are solid particles. When a tissue is infected and the bacteria have overcome the local resistance of the white cells, or when the pus formed is put under such pressure that it is forced into the tissue spaces, the bacteria enter the lymphatics. If, instead of following these channels, they entered the blood, they would be carried immediately to every part of the body and would give rise to generalized infection. What is true of bacteria is also true of cancer. Cancer is spread by cells which separate from the initial growth and are carried to other parts of the body. Cancer usually spreads along lymph channels rather than through the circulation of the blood.

Lymph Nodes.

Lymph flows finally into the blood of the veins, but before it is thus emptied it is passed through structures serving as filter sta-

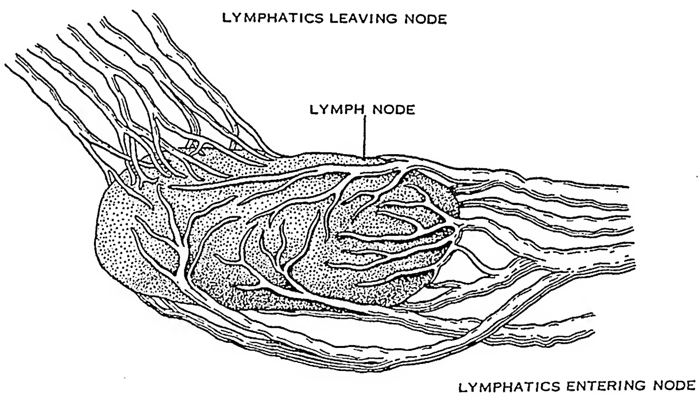

Figure 18. Lymph Node.
Showing lymphatics entering and leaving.

tions which retain or destroy any foreign bodies the lymph may contain. These structures are known as lymph nodes. The blood is not similarly freed of foreign solids. In that fact lies the advantage of having bacteria carried by the lymph rather than the blood. Lymph nodes are glands in which the white corpuscles are formed. When the lymph nodes retain bacteria they become swollen and painful. A sore throat or tonsilitis causes the glands in the neck to swell; severe infection of the hand may bring into

prominence a group of glands in the arm pit; an infection of the foot or leg similarly affects the glands in the groin. On careful inspection a narrow pink streak, an inflamed lymphatic, can be seen extending from the point of infection on the hand or foot up to the lymph glands in the arm pit or groin. In pulmonary tuberculosis the lymphatic glands of the lungs are affected. The particles of carbon from the coal dust and smoke which are inhaled are also collected in these lymph glands.

Bacteria which have been stopped by a lymph gland sometimes cause an acute inflammation of the gland. Pus then collects and an abscess forms. An abscessed gland of the groin is known as a bubo. Tubercular abscesses in the glands of the neck are common in children. The bacteria are absorbed from the mouth or throat, are stopped by the glands in the neck, and the tubercular infection centers there. It may then be necessary for the glands to be removed by surgical operation. When the lymph glands are unable to cope with the bacteria which reach them, the organisms escape into the blood stream giving rise to septicemia, commonly called blood poisoning.

The cancer cells which are filtered out by lymph glands grow in the glands, making them a center for a new cancer. It is the practice in operating for cancer to remove not only the primary growth, but also the lymph glands through which the locality is drained. Thus in removing a cancer of the breast the glands in the arm pit are also removed.

Tonsils.

The lymph glands located beneath the mucous membrane of the pharynx are spoken of as tonsils. There are a number of these glands, but unless they are abnormally swollen only a few are evident. The most prominent are a pair, the faucial tonsils, occupying a space on each side of the throat between the vertical folds of flesh which run together to form the soft palate. The pharyngeal tonsil, or adenoid, is located on the back wall of the nasal pharynx, the passage leading from the nose to the throat. This gland is particularly prominent in children. A less definite collection of lymphatic tissue, the lingual tonsil, occurs on the back of the tongue. This may become swollen as a result of irri-

tation by tobacco smoke, causing the chronic cough often associated with cigarette smoking. The lymph nodes beneath the mucous membrane about the openings of the eustachian tubes may become swollen as a result of a cold in the head. Temporary impairment of hearing results from the closure of the tubes.

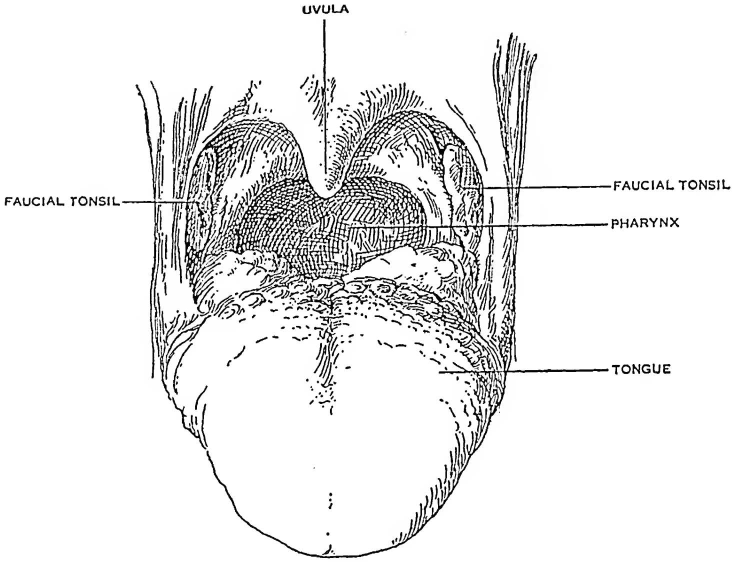

Figure 19. Faucial Tonsils.

The faucial tonsil on each side of the throat occupies a space between the vertical folds of flesh which run together into the soft palate. The adenoid tonsil is shown in figure 7.

Enlargement of the Tonsils.

In childhood all of the lymphatic tissue of the body is relatively large; the tonsils and adenoids may be very prominent. After middle life the normal tonsil does not rise above the surface of the mucous membrane, and therefore is not apparent. The size of the projecting portion of the tonsil does not indicate the size of the mass which may be buried under the mucous membrane.

Chronic enlargement of the tonsils and adenoids may have an adverse influence upon the bodily and mental development of children. The condition is one of the most common and important affections of childhood. The immediate effect of the condition is a partial obstruction of the respiratory passage which

results in mouth breathing. The secondary effects are deformation of the chest, changes in the facial expression, partial deafness, and in some cases stunting of the growth. When mouth breathing has existed for a long time the expression is dull and apathetic; the mouth is habitually held open. The child is stupid-looking, responds slowly to questions, and may be sullen and cross. The lips are thick and the nasal openings small and pinched. The roof of the mouth is raised and the upper dental arch narrowed. The condition of pigeon or chicken breast is the most common deformity of the chest which results from the impediment of breathing caused by adenoids. The breast bone is prominent and sharp, the ribs are depressed. The funnel breast is another type of deformity which may in some instances be caused by adenoids. The lower part of the breastbone is sunken in a funnel-shaped depression. Children with adenoids are prone to take cold and to have recurrent attacks of tonsilitis.

Infection of the Tonsils.

The tonsils have a particular significance in that they are a common site of local infection and a common entrance for general infection. The outer surface of the tonsil is irregular; the mucous membrane folds into pits or crypts of various sizes. The larger of these crypts may expand beneath their orifice so that the secretions collect and are retained in them. Bacteria lodged in the crypts grow actively and give rise to acute or chronic tonsilitis. In the more severe form of local infection the tonsils become painful and are red and swollen. They may enlarge to such an extent that they meet in the middle of the throat. The crypts are filled with a malodorous cheese-like material made up of bacteria and dead white cells. The lymphatics from the tonsils drain into the lymph nodes of the neck. In tonsilitis these glands may become enlarged and painful. General symptoms are caused by the absorption of the products arising from the bacteria; chills, fever, pain in the back, headache, and some degree of prostration are the most common symptoms. Acute tonsilitis occurs particularly in the spring of the year. Wet feet and chilled skin are predisposing factors. The infection is transmitted by the bacteria contained in the spray of saliva emitted during coughing, sneezing, or even

speaking. Less commonly the transmission is through milk or articles of common contact. It may come from an infection of the teat of a cow whose milk is used.

In chronic tonsilitis the tonsils are enlarged, as are also the glands in the neck. There is usually no marked pain and only moderate redness of the tonsils. A few of the crypts may show collections of cheesy material. Chronic tonsilitis is readily aggravated into the acute condition. Chronic tonsilitis causes some degree of sepsis, that is, poisoning from the absorption of the products arising from the local infection. Those afflicted tire easily, lack normal energy and stamina, and are subject to pain in the joints and muscles.

It is not necessary for the bacteria to enter the blood through the tonsils in order to cause ill health. This fact is particularly evident in diphtheria. This disease is primarily a local infection of the tonsilar tissue; the severe and frequently fatal effects result from the absorption of the toxin or poison generated by the bacteria growing on the surface.

The entrance of bacteria may be followed by an abscess formed in the substance of the tonsil. Such a condition is known as quinsy. More often the bacteria which enter pass into the blood stream without causing an abscess in the tonsil. In this respect local infection of the tonsil with the absorption of the organisms and their products is comparable to pockets of pus about the teeth. In recent years emphasis has been laid upon these foci of infection as a possible source of inflammatory rheumatism, heart disease, disease of the kidneys, and nervous disturbances.

CHAPTER VIII

RESPIRATION AND THE VITAL COMBUSTION

OXYGEN is as essential for the vital combustion as is the fuel afforded by the foodstuffs; for it is by means of oxidation that the energy of the foodstuffs is liberated and made available for work and heat. Oxygen is taken into the body by way of the lungs and carried to the tissues by the circulating blood. The same process carries carbon dioxide from the tissues to the lungs for elimination. Respiration includes all of the processes by which oxygen is delivered to the tissues, and carbon dioxide is removed from them and discharged from the body.

The exchange of gases between the blood and the air in the lungs is called external respiration; the exchange between the blood and the tissues is internal respiration. External respiration and internal respiration are connected by means of the circulation of the blood; and the heart pumping the blood around is really the chief respiratory organ; it is the limiting factor in physical vigor.

External respiration involves the act of breathing, by which air is periodically drawn into and expelled from the lungs. We are unconscious of internal respiration; nevertheless it is the rate of internal respiration which controls the activity of breathing. The rate of internal respiration, in turn, is determined by the activities of the tissues of the body; these activities are the oxidation of carbohydrates and fats with the liberation of energy. The amount of oxygen taken from the blood by the tissues and the corresponding amount of carbon dioxide returned to the blood, vary in proportion with the rate of internal respiration. The amount of air breathed corresponds to these variations. Likewise the variations in the amount of gases transported between the air and the tissues involve a corresponding adjustment of the activity of the transporting agent, the circulation of the blood. This activity is controlled by the heart.

Thus respiration involves both breathing and the circulation of the blood, and the activity of these two functions is deter-

mined by the rate at which energy is liberated within the body. When a man exercises he breathes more air and his heart beats faster; but it is important to notice that he first does the work and then breathes more. The ordinary heat engine, such as a steam engine, must first have a large supply of air before it can do work. The relations are exactly the opposite in the living body.

The lungs consist of thin membranes folded into a great many small sacs. These sacs are open to the external air by way of the bronchial tubes and trachea. Between the folds lies a net-

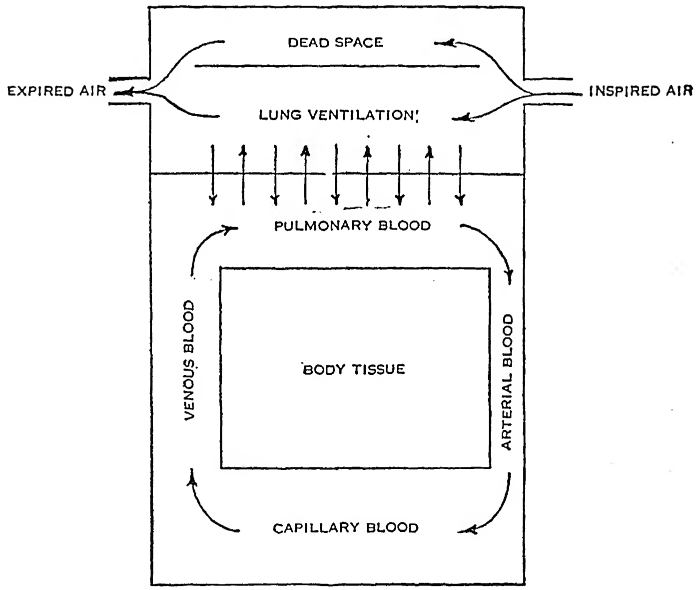

Figure 20. Diagram Showing Relations of Circulation, Body Tissue, and Air in the Lungs.

work of capillaries. As the capillaries of the lungs form the only path through which the blood flows from the right side of the heart to the left side, all of the circulating blood passes through the lungs at each round of the circulation. In its passage the blood comes into gaseous equilibrium with the air in the lungs; carbon dioxide passes out of the blood and oxygen passes in until the pressures of each gas in the blood and in the air are the same.

Arterial blood is distributed to all parts of the body. The working tissues have, as a result of their activities, a greater pressure of carbon dioxide, but a lower pressure of oxygen, than

the blood. In passing through them oxygen leaves the blood, passing from the capillaries to the tissues, while carbon dioxide passes from the tissues into the blood. The blood leaving the capillaries contains more carbon dioxide but less oxygen than the arterial blood. This blood is collected in the veins and is pumped by the right side of the heart through the capillaries of the lungs for equilibration with the air in the lungs.

In Figure 20 the relations of the lungs, the circulating blood, and the tissues are illustrated, but in a much simplified diagram. The compartment at the top represents the lungs. Instead of a vast number of minute sacs opening to the air, the lungs are here figured as a single chamber. Moreover, the air is shown as entering at one side and emerging from the other, whereas in the body it is alternately drawn in and forced out through the same passageway. The central block in the figure represents the tissues of the body. The area surrounding the center represents the circulating blood. The layer of blood at the top is that flowing through the capillaries of the lungs. This blood exchanges gases with the air in the lungs; the exchange is indicated by arrows for carbon dioxide leaving and oxygen entering the blood. The layer of blood to the right of the tissues represents the stream in the arteries. No exchange of gases takes place through the arteries. The layer of blood below the tissues represents the stream through the capillaries. Here the blood exchanges gases with the tissues, oxygen leaving and carbon dioxide entering the blood. The venous blood is shown returning to the lungs to the left of the "tissues." As in the case of the arteries, no exchange of gases takes place through the veins.

Adjustment of Breathing to Rate of Internal Respiration.

The volume of air breathed by a man resting or exercising is chiefly regulated not by the demand for oxygen, but by the production of carbon dioxide. This control seems as if designed to afford an excess of oxygen under all conditions except those of violent muscular exertion. Thus it has been said, "carbon dioxide spreads its protecting wings over the oxygen supply of the body." The blood leaving the lungs contains under all ordinary circumstances much more oxygen than the tissues draw for their needs.

Carbon dioxide is added to the blood by the tissues in amounts determined by the activities of the tissues. It is by the varying amounts of carbon dioxide added to the blood that breathing is adjusted to the rate of internal respiration. The amount of air breathed in any period of time is that necessary to remove the excess of carbon dioxide from the venous blood coming to the lungs so as to maintain a uniform and rather high concentration of carbon dioxide in the arterial blood leaving the lungs.

Carbon dioxide dissolves in blood just as it does in water or any other fluid; but in addition the blood is capable of holding a much greater amount in loose chemical combination. Carbon dioxide is an acid substance when it is dissolved in water, for part of it reacts with water with the formation of carbonic acid, H_2CO_3. The reaction is as follows:

$$CO_2 + H_2O \rightleftarrows H_2CO_3$$

This reaction is reversible, so that the amount of acid formed varies with the amount of carbon dioxide absorbed and hence with the pressure of carbon dioxide to which the fluid is exposed.

The blood contains inorganic alkaline substances and also proteins which hold alkali. The blood is capable of converting some of the sodium chloride which it contains into alkali by absorbing the chlorine into the red corpuscles. When carbonic acid enters the blood it combines with the alkali and is neutralized. Blood is slightly alkaline under all conditions, but its degree of alkalinity varies with the extent to which its available alkaline substances have been neutralized by the carbonic acid.

The amount of alkaline substances in the blood is constant under conditions of health and residence at any one altitude. Most of these alkaline substances come from the food eaten, and the uniformity of their amount in the blood is maintained by the selective secretory activity of the kidneys. If the diet contains more alkaline substances, from fruit and vegetables, than the blood requires, the excess is eliminated through the urine, which becomes alkaline; conversely, when the diet contains an excess of acid substances, arising from the metabolism of protein (especially from its sulphur and phosphorus) they are secreted through the urine, which becomes acid (see Chapter XI).

Since the alkaline substances in the blood are normally maintained in constant amount, the only variable affecting the alkalinity of the blood is the amount of carbon dioxide dissolved in it. When blood is exposed to carbon dioxide at a pressure greater than that of the carbon dioxide already in the blood, carbon dioxide enters and the alkalinity of the blood is diminished. If the blood is then exposed to air containing carbon dioxide at a pressure lower than that in the blood, carbon dioxide passes out into the air and the alkalinity of the blood is increased. The first of these conditions occurs in the tissues, the second in the lungs.

The activity of breathing is controlled by a nerve center in the brain. This center is sensitive to slight variations in the alkalinity of the arterial blood which reaches it. If the alkalinity is reduced below the normal value, breathing is increased, so that more carbon dioxide is removed from the blood passing through the lungs and the alkalinity of the arterial blood is restored to normal. If the alkalinity is increased above the normal value, breathing is reduced or stopped until sufficient carbon dioxide has accumulated in the blood to restore the normal alkalinity.

Volume of Air Breathed.

Blood has the normal degree of alkalinity only when it has been exposed to and brought into equilibrium with air containing an exact percentage of carbon dioxide. At sea level in healthy people this amount of carbon dioxide is 5.5 per cent of the pressure of one atmosphere. The air in the lungs to which the blood is exposed is so regulated that it contains constantly this amount of carbon dioxide. The volume of air breathed for any rate of production of carbon dioxide is the amount of air necessary to dilute this carbon dioxide to 5.5 per cent.

For a summary of these facts we may again refer to the diagram, Figure 20. The air in the compartment indicated as the lungs contains 5.5 per cent of carbon dioxide because the flow of air is adjusted to the amount of the gas coming to the lungs so as to maintain this amount. The arterial blood leaving the lungs has a degree of alkalinity corresponding to this percentage of carbon dioxide. This blood circulates to the tissues, where carbon dioxide is added to it. The blood with the added carbon

dioxide circulates to the lungs. There it gives up some of its carbon dioxide to the air in the lungs. If the carbon dioxide in the air in the lungs is to be maintained at the normal level of 5.5 per cent, air must be brought in to dilute the carbon dioxide. The amount of air breathed into the lungs in any period is exactly the amount of air necessary to dilute the carbon dioxide brought to the lungs in that time down to 5.5 per cent; no less but no more.

On this basis the amount of air breathed per minute can be calculated for any rate of production of carbon dioxide. The tissues of man at rest produce each minute between 200 and 300 cubic centimeters of carbon dioxide. For the first of these values a normal man will breathe so that 3.6 liters of air will be passed in and out the lungs each minute; for the second, 5.4 liters. These two volumes are, respectively, the amounts of air necessary to dilute 200 and 300 cubic centimeters of carbon dioxide to a concentration of 5.5 per cent; that is, 200 cubic centimeters is 5.5 per cent of 3.6 liters and 300 is 5.5 per cent of 5.4 liters. Under moderately vigorous exercise the tissues of the man produce approximately 1 liter of carbon dioxide each minute; by the same calculation the volume of air passed in and out of his lungs in this time would be 18 liters. In extreme exertion the amount of CO_2 produced each minute is between 3 and 4 liters; the corresponding volumes of air are 54 and 72 liters.

The volume of air passed in and out of the lungs and equilibrated with the blood is not the same volume as the air breathed. Approximately one-third of the air inhaled does not reach the lungs; it merely fills the pharynx, windpipe, and bronchial tubes, the so-called respiratory dead space. During expiration this air is breathed out and is followed by the two-thirds of the previously inspired air which has reached the deeper portions of the lungs. In Figure 20 the dead space is illustrated as a partition dividing the compartment of the lungs. The air passing over this partition is in the dead space, that passing below is in the deeper parts of the lungs; only the latter takes part in the exchange of gases with the blood. Although the air in the lungs, equilibrated with the blood, contains uniformly 5.5 per cent of carbon dioxide, the expired air contains only about 3.5 per cent, thus showing a dilution of about one-third. The volume of air breathed by the man

in the example given in the previous paragraph is greater by 50 per cent than the volumes given there as the air passed through his lungs. His actual volume of breathing per minute, with this allowance made for the dead space, would be between 5.4 and 8.1 liters at rest instead of 3.6 and 5.4 liters; 27 liters for moderate exertion instead of 18 liters; and between 81 and 108 liters for extreme exertion, instead of 54 to 72 liters.

Transportation of Oxygen in the Blood.

Oxygen is carried in the blood in loose chemical combination with hemoglobin. Some oxygen is also dissolved in the blood, but the amount is small, just as it would be in water. The arterial blood normally contains about one-fifth of its volume of oxygen; that is, each 100 cubic centimeters of arterial blood hold approximately twenty cubic centimeters of oxygen. Of these twenty cubic centimeters only 0.5 are in solution; the remainder is combined with the hemoglobin.

The reversible reaction between hemoglobin (symbol Hb) and oxygen is expressed by the equation:

$$Hb + O_2 \rightleftarrows HbO_2$$

When blood is exposed to atmospheric air the hemoglobin takes up oxygen and becomes oxyhemoglobin; when the blood is exposed to air or to tissues containing a less amount or pressure of oxygen, some of the oxygen passes from the blood and part of the oxyhemoglobin is reduced to hemoglobin. The reaction in the first direction occurs in the lungs, where the blood takes up oxygen; the reaction in the second direction occurs in the tissues, where the blood gives up oxygen. Thus the arterial blood contains more oxygen than the venous blood. This difference during rest amounts to from 3 to 5 cubic centimeters of oxygen for each 100 cubic centimeters of blood. During exercise the difference increases and may amount to 10 or 12 cubic centimeters, depending upon the activity of the tissues and upon the rate of the circulation.

In the lungs the pressure of oxygen, in the per cent of an atmosphere, is about two-thirds of that in the outside air. This pressure of oxygen is sufficient ordinarily to convert nearly all of the hemoglobin into oxyhemoglobin; only a very little more oxygen could be carried by the blood if pure oxygen were breathed

instead of air. When blood in a closed vessel is exposed to a pressure of oxygen below that in the lungs, oxygen comes off, at first less rapidly than the fall in pressure, so that at half the pressure in the lungs only about 10 per cent of the oxygen is withdrawn. Below this pressure the amount retained by the blood diminishes nearly in proportion to the decrease in pressure. The amount of oxygen in the blood and the per cent of the hemoglobin in combination with oxygen, plotted against the pressure of oxygen to which the blood is exposed, give an S shaped curve which

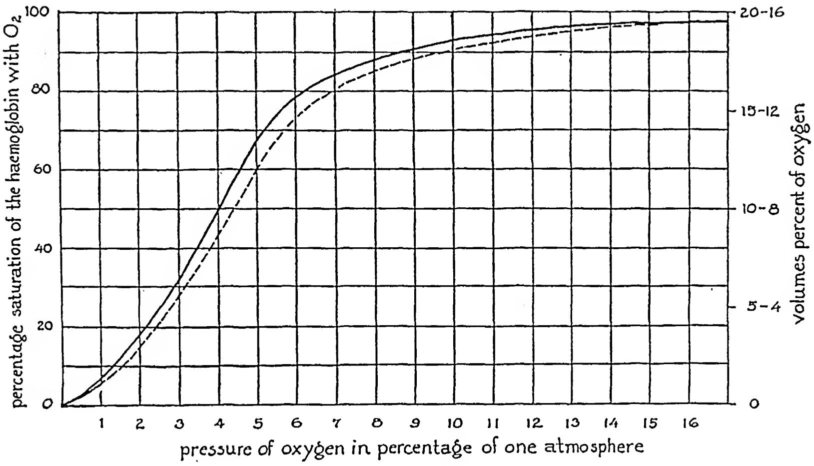

Figure 21. Oxyhemoglobin Dissociation Curve.
Solid line: in presence of 40 m.m. carbon dioxide. Broken line: in the body.

rises rapidly and then gradually flattens. Such a curve is called the dissociation curve of oxyhemoglobin; it is illustrated in Figure 21.

Influence of Oxygen upon Control of Breathing, and Acclimatization to Altitude.

The pressure of oxygen in the air breathed, while constant for any one altitude, diminishes with increasing altitude above sea-level. In consequence the volume of air breathed at sea-level does not maintain within the lungs as great a concentration of oxygen at a high altitude. The production of carbon dioxide is not influenced by the altitude, for it comes from the tissues and not from the air. It is important that the volume of breathing shall be so

adjusted to the rate of carbon dioxide production that the oxygen is adequately supplied. The basic adjustment of breathing to correspond to a diminished pressure of oxygen in the air is effected by the oxygen acting through the alkaline substances of the blood. When the pressure of oxygen in the air is lowered, as in going to a higher altitude, the alkaline substances of the blood are slowly diminished until a new level is reached. When the pressure of oxygen in the air is increased, as in returning to the lower altitude, the alkaline substances in the blood are slowly increased until they return to their former amount. The alteration in the amount of alkaline substances in the blood influences the regulation of breathing through the following process: The normal alkalinity of the arterial blood is the same for full acclimatization to all altitudes. This alkalinity, as explained above, is the balance or ratio between the amount of alkaline substances in the blood and the amount of carbon dioxide in the blood. In order to maintain a constant alkalinity with a diminished amount of alkaline substances in the blood, the carbon dioxide must also be diminished. In order to maintain this lower level of carbon dioxide in the blood a greater dilution of the carbon dioxide must take place in the lungs. The concentration of carbon dioxide in the air in the lungs must therefore be reduced from the 5.5 per cent normal at sea-level to some lower percentage; in Denver, Colorado, altitude 5,400 feet, the carbon dioxide in the lungs is 4.5 per cent of an atmosphere. By the principles of dilution the amount of air passing through the lungs for any rate of production of carbon dioxide must increase in proportion as the per cent of CO_2 maintained in the lungs is decreased. The greater volume of breathing brings more oxygen to the lungs to combine with the hemoglobin and thus in part compensates for the lower pressure of oxygen in the air. People at high altitude breathe more air for a given exertion than they do at sea-level. On going from a high altitude to a low altitude the conditions described are reversed; under the influence of the increased pressure of oxygen alkaline substances accumulate in the blood, and the per cent of carbon dioxide rises until it becomes normal to the new altitude.

The process of adjustment to altitude here described is slow; it takes days or even weeks for the changes in the alkaline substances

in the blood to reach completion and a new equilibrium. Deficiency of oxygen has also an immediate effect upon breathing. Although for established conditions of oxygen in the air it normally plays no evident part in the control of breathing, which is exercised almost wholly through carbon dioxide, nevertheless the need for oxygen can, if conditions demand it, take the control of breathing away from carbon dioxide. The usurpation of control occurs in high altitudes before the slower adjustment through the diminution of alkaline substances has taken place. In a man going to high altitudes, or breathing air deficient in oxygen, breathing is controlled at first directly by the deficiency of oxygen. The character of the breathing is then different from the ordinary type. The volume of oxygen in the body is much less than the volume of carbon dioxide; the same change of volume makes a greater percentage difference in the oxygen. In consequence, breathing is uneven; it behaves like an engine with too delicate a governor. This type of breathing is called Cheyne-Stokes breathing; there are a few deep breaths followed by a pause, then a crescendo in the size of the breaths culminating in the deep breaths after which there is a pause. The cycle is then repeated. The breathing assumes more nearly the normal character when acclimatization has been effected. Some people breathe in this way when asleep; it is common in persons with heart disease for at sea-level they are as short of oxygen as a normal man on a mountain.

Experiments Demonstrating the Control of Breathing.

Two simple experiments serve to demonstrate that the volume of air breathed is regulated by the carbon dioxide in the arterial blood: When the breath is held carbon dioxide accumulates in the air in the lungs, for it is brought there continually by the venous blood. As the concentration rises a correspondingly greater amount remains in the arterial blood, for the blood is at every instant in equilibrium with the lung air. The alkalinity of the blood is momentarily diminished. As a result the demand for breathing becomes increasingly insistent until finally a breath must be taken. The length of time the breath can be held is determined by the rate of carbon dioxide production in the body and

by the amount of alkaline substances which the blood contains. During or immediately after muscular exertion the breath can be held for only a brief period, for the rapid production of carbon dioxide causes a correspondingly rapid increase in the carbon dioxide in the blood. When the blood alkali is reduced for any reason, for example in some forms of disease of the kidneys, the time that the breath can be held is shortened. The average person at rest can, after taking a single deep inspiration, hold his breath for a period of thirty seconds to one minute. If, now, instead of a single inspiration, a series of very deep inspirations and expirations are made, so-called "forced breathing," for one or two minutes and with the last inspiration the breath is held, it can be so held for a period of two to four minutes. To produce this result the forced breathing must be real; there is a tendency after the first few deep breaths to curtail the amount of air moved. The forced breathing brings to the lungs a greater volume of air than is required to dilute the carbon dioxide produced in the body during the time to the normal 5.5 per cent. The desire to breathe does not arise until the carbon dioxide has accumulated to the normal level. In holding the breath after prolonged forced breathing the blood is largely depleted of its oxygen before the carbon dioxide has accumulated to the point at which breathing is stimulated. Under such circumstances the oxygen deficiency assumes control of breathing. By doing forced breathing and with the last inhalation filling the lungs with oxygen, the breath can be held for six to eight minutes; the record is over 13 minutes.

Acidosis and Alkalosis.

The degree of alkalinity of the arterial blood under normal circumstances is as constant as is the temperature of the body. Just as the temperature may be disturbed under certain circumstances, so also may the alkalinity of the blood. If the amount of carbon dioxide in the lungs and in the blood is high in proportion to the amount of alkaline substances, the blood is less than normally alkaline; this condition is called acidosis. In the reverse condition the carbon dioxide is low in proportion to the alkaline substances and the blood is more alkaline than normal; this condition is called alkalosis.

Alkalosis occurs when the volume of air breathed is increased out of proportion to the production of carbon dioxide. Thus in the experiment with forced breathing described above the excessive amount of air breathed dilutes the carbon dioxide in the lungs to a subnormal level and alkalosis develops. This condition is also called acapnia from the Greek *kapnos,* or smoke, and indicates lack of carbon dioxide or "smokelessness." Alkalosis is accompanied by changes throughout the body; the blood pressure is diminished, there is dizziness, pain in the head, and in severe alkalosis even nausea and vomiting. The condition known as mountain sickness is partly due to alkalosis. The diminished oxygen in the air at the high altitude results in overbreathing because oxygen deficiency and not carbon dioxide is controlling breathing. The symptoms of mountain sickness are those of alkalosis. They disappear when the alkalosis is relieved by the diminution of alkaline substances of the blood to the level proper to the altitude, and breathing is again controlled by carbon dioxide.

Acidosis occurs when the volume of air breathed is diminished out of proportion to the production of carbon dioxide. In holding the breath without preliminary forced breathing carbon dioxide accumulates in the lungs and acidosis develops. During exercise there is a mild degree of acidosis, for the breathing does not, as a rule, fully keep up with the production of CO_2. Unlike alkalosis, acidosis does not produce unpleasant effects unless the condition is very severe. In acidosis there is an increasing desire to breathe, the blood pressure is elevated, and the head may throb.

Acidosis is produced by some diseases as well as by the temporary conditions of holding the breath and by exercise. In certain diseases of the kidneys nonvolatile acids are believed to accumulate in the blood and to combine with the blood alkali; so also in the acidosis of acute diabetes. These acids cannot be ventilated out of the blood in the lungs as can carbonic acid, and the amount of alkaline substances available for combination with carbonic acid and to balance its acidity, is thus diminished. Normally the kidneys would rapidly remedy this condition by secreting an excess of nonvolatile acids in the urine, but the diseased kidneys cannot do so. Persons so affected breathe excessively on slight exertion and can hold their breath only for a short time.

Many erroneous ideas have been promulgated in regard to acidosis by diet faddists. The blood under no circumstances becomes acid during life. In fact, the diet, unless it is extremely abnormal, has little influence upon the balance of acid and alkaline substances in the blood, for the kidneys regulate the alkali to its proper level. It is only when the kidneys fail in their function that the balance is disturbed, and the diet may then play an important part in maintaining the proper level of alkali. Even then the action of the substances in the foods liberating alkali and acid is indirect, and any special diet is intended primarily to spare the kidneys unnecessary work.

Pressure of Atmospheric Gases.

The terms pressure and per cent of gas, as applied to the carbon dioxide and oxygen in the lungs, have been used together here, but they are not synonymous. The distinction is important for the discussion of disturbances arising from exposure to high atmospheric pressure.

The air above the earth is pressed down by its weight. The barometer is the instrument used to measure this pressure. At sea-level the weight of the air above the earth supports a column of mercury in the barometer 760 millimeters high, 760 millimeters of mercury equivalent to 15 pounds to the square inch. With higher or lower altitudes the barometer rises or falls in accord with the thickness of the layer of air. Thus at an altitude of 23,000 feet the barometer stands at only one-half its sea-level value. This is the height to which some of those who attempted to ascend Mt. Everest became more or less acclimatized.

When a mixture of gases is compressed, each gas within the mixture exerts an individual or partial pressure equal to its fraction in the mixture. The sum of all the partial pressures equals the total pressure upon, and in, the mixture. Air is a mixture of (very nearly) 21 per cent oxygen with 79 per cent of nitrogen and other inert gases and a negligibly small amount of carbon dioxide (.03 per cent). Since at sea-level the pressure exerted upon, and by, the air is 760 millimeters, the partial pressure of the oxygen, in perfectly dry air, is 21 per cent of 760 millimeters, or 160 millimeters; and the partial pressure of the nitrogen (in-

cluding other inert gases) is 79 per cent of 760 millimeters, or 600 millimeters. At an altitude of 14,000 feet, that of Pike's Peak, Colorado, where the barometer stands at 450 millimeters, the per cent of oxygen and nitrogen remains the same as at sea-level; but as the total pressure is decreased, the partial pressures of the two gases are only 95 millimeters and 355 millimeters, respectively (95:355: :21:79).

The amount of any gas dissolved in a fluid with which it is in contact varies with the partial pressure of that gas, but is otherwise independent of the per cent of the gas in the mixture. Thus twice as much oxygen dissolves in water exposed to air at sea-level as dissolves in water exposed to air at 23,000 feet elevation, for the partial pressure of oxygen is there diminished to one-half its sea-level value. The amount of oxygen in combination with hemoglobin is also influenced by the pressure independently of other gases present. Thus at an altitude of 23,000 feet it would be necessary to breathe air containing twice the normal percentage of oxygen, and hence having the normal partial pressure, in order to bring the same amount of oxygen into the blood as at sea-level. For this reason aviators who fly to high altitudes inhale oxygen. At a pressure of 160 millimeters an atmosphere of pure oxygen would have a pressure just equal to the partial pressure exerted by the oxygen at sea-level and the blood would take up the corresponding amount of oxygen. Conversely, an atmosphere containing only 5¼ per cent of oxygen would be as good as normal air for a man working in a caisson under a pressure four times as great as that at sea-level, 45 pounds gauge pressure.

Partial Pressure of Oxygen in Relation to Vital Combustion.

Oxygen is necessary to support life. When the blood fails to bring sufficient oxygen to the tissues to support their activities, unconsciousness results and death follows. The same is true of any type of combustion, such as that of a candle, but with the difference that the candle is extinguished when the percentage of oxygen in the air is insufficient, while life depends not on the percentage but on the partial pressure of oxygen. Since the oxygen which reaches the tissues of a man must first be dissolved,

its amount in the blood depends upon the partial pressure rather than upon the percentage of the gas in the mixture breathed. The behavior of a man and that of a candle flame are different in respect to a low per cent of oxygen and a low pressure of oxygen. A candle flame is extinguished when the oxygen in the air falls below 16 per cent. A man at sea-level is not appreciably affected by this fall in oxygen, for the pressure at 16 per cent of an atmosphere is 122 millimeters, equivalent to the pressure of oxygen in the air at an altitude of 5,500 feet (about the altitude of Denver, Col. or Mt. Washington, N. H.) A compression of the air to a thousand millimeters of mercury (about 4½ pounds gauge pressure) would restore the oxygen to a normal partial pressure, but still the candle would not burn, for the per cent of oxygen is not altered by the change in pressure. If the man and the candle were taken to high altitudes, the candle would burn quite well long after the man had collapsed; for, although the pressure of oxygen is diminished, its percentage remains constant.

The man and the burning candle are also different in their reaction to a pressure or percentage of oxygen increased above that of sea-level. The candle flame burns more brightly when the percentage of oxygen is increased above the normal 21 per cent; but increased pressure of air does not influence the flame. The combustion in the man is influenced by neither factor, popular superstition to the contrary. The hemoglobin of the blood is nearly saturated with oxygen at the ordinary pressure of oxygen in the air; increasing the pressure or per cent adds only an insignificant amount by simple solution. Moreover, the vital combustions are not regulated by the volume of air breathed as an ordinary combustion in a stove is influenced by the draft, but instead the body's energy expenditure determines the oxygen consumption.

Effects of High Atmospheric Pressure; Diving and Caisson Work.

The effects of exposure to high atmospheric pressure illustrate the laws of solution of gases in fluids. Men are exposed to high atmospheric pressure in diving and in engineering work carried out under water in caissons and submarine tunnels. The highest

pressures are encountered in deep diving, and may reach ten atmospheres, 135 pounds gauge pressure.

The dress of the diver consists of a copper helmet which screws to a metal corselet over his shoulders, which is clamped water-tight to a stout suit of rubber, covering the whole body except the hands, which project through elastic cuffs. Air is supplied to the diver through a hose attached to the helmet. Air escapes at the side of the helmet through a spring valve; this valve is adjusted by the diver to maintain the air pressure within the helmet at a pressure slightly above that of the surrounding water.

For every thirty-two feet of fresh water or thirty-one feet of salt water, the pressure increases by one atmosphere, or nearly fifteen pounds to the square inch. It is absolutely necessary that the diver shall be continually supplied with compressed air so as to maintain the same pressure within his lungs as about his body. If the air pressure fails at a great depth, his breathing is stopped by the weight of the water against his abdomen and chest, so that blood is squeezed up to his head in the inelastic helmet and pours from his nose and mouth, causing death.

A caisson is a chamber, sunk under water, with walls and roof but no floor, as the caisson rests on the bottom; it allows the men within it to excavate the dirt or rock and thus the caisson sinks. The top of the caisson is provided with air locks or chambers closed by two air-tight doors. Compressed air is pumped into the caisson under sufficient pressure to force back the water which would otherwise enter the bottom. The workmen enter and leave the caisson through the air locks formed between the two doors. In tunneling operations under water the space back of an advancing shield is supplied with compressed air, and the entrance of water into the end is thus prevented. The railway and vehicular tunnels under the Hudson River were constructed in this manner.

Various physiological disturbances are associated with exposure to compressed air. As the pressure rises the first trouble usually noted is a sense of pain and pressure in the ears. This is due to an unbalanced pressure in the middle ear from failure of the eustachian tubes, the passage from the throat to the middle ear, to open freely. The passage is liable to be blocked if the man has

catarrh or a cold. It can usually be forced open and the pressure equalized by swallowing or by blowing with the mouth shut while the nose is clamped with the fingers. In men accustomed to compressed air the eustachian tube opens easily so that a diver can pass to a pressure of six or seven atmospheres in two or three

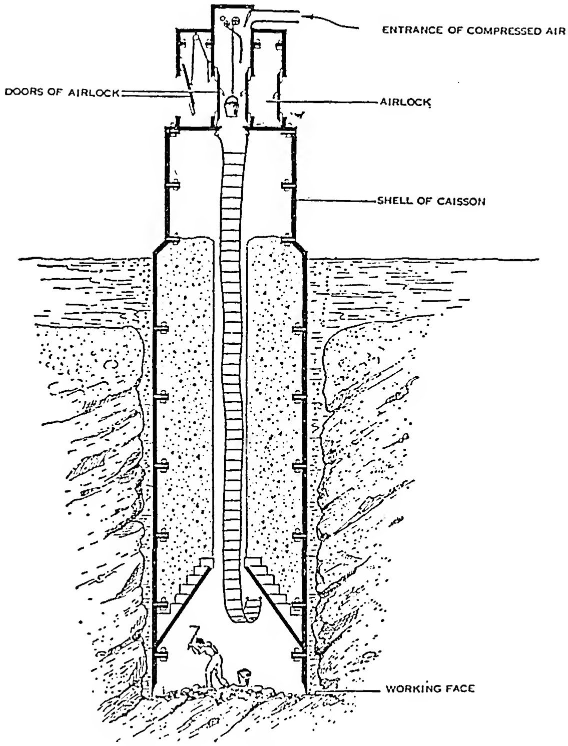

Figure 22. Schema of Caisson.

The shell of the caisson is sunk in water and extends into an excavation made in the rock below the water. Water and mud are kept from entering the open end, where the men work, by the pressure of the air pumped into the shell. At the top of the caisson are air locks shut off from the compressed air by doors. The men emerging from the caisson undergo decompression in these air locks.

minutes; but the uninitiated may have a long struggle with the eustachian tube before they can be comfortable in a pressure of even an extra half of an atmosphere; a rapid increase in pressure may result in the rupture of the head of the ear drum. If the sinuses, which open into the nasal canal, are inflamed or catarrhal they may also give rise to pain. The same difficulty with the ear

may be met, though to a less degree, in the rapid descent of an airplane, or even in descending a deep mine shaft, or in the elevator of a high building.

The chief dangers from working under compressed air do not arise, however, from the pressure of the air to which the men are exposed, but from the increased pressure of the gases in the air breathed. If the air breathed is pure the only gases which come into consideration are nitrogen and oxygen. If the air is rendered impure by breathing, as may be the case with a diver, carbon dioxide is also of importance. With a constant per cent of carbon dioxide in the partially vitiated air within the helmet, the partial pressure of the carbon dioxide rises in proportion to the pressure of the compressed air; and the physiological effect of the gas is dependent solely upon the partial pressure. Thus contamination of the air in the helmet with 2 per cent of carbon dioxide (18 mm. partial pressure) before descending into the water would produce no considerable effect, whereas the same per cent under five atmospheres would be equivalent to 10 per cent of carbon dioxide under ordinary pressure or 90 millimeters partial pressure, an amount which would incapacitate the man for any exertion. Thus both the volume of air supplied to the diver, and its pressure are important. The ventilation must be increased in direct proportion to the depth and pressure at which the diver works.

By far the most serious danger to workers under compressed air is experienced not while they are "in the air," but after they have been decompressed to atmospheric pressure. In all work in compressed air it has been observed that soon after coming out some of the men become ill and that some die or become paralyzed. The likelihood of these complications increases with the pressure and the duration of exposure. This form of illness is not experienced during the stay under pressure; it is only after decompression that the symptoms come on. In the worst cases the man collapses and in a few minutes is dead. In less serious cases his legs become paralyzed and he has what is known as diver's paralysis. In the slight cases, once very common among caisson and tunnel workers, there is severe pain in the limbs or in the body, known among the workmen as the "bends." The

various symptoms which may develop after decompression are spoken of as caisson disease.

The cause of caisson disease lies in the high partial pressure of nitrogen to which those working in compressed air are exposed. Gaseous, or elemental nitrogen, is not utilized in the body. The gas is dissolved in all the fluids and tissues of the body at the partial pressure which exists in the surrounding air. The amount of nitrogen in solution remains constant so long as the pressure of the air is maintained uniform. When the pressure of the air is increased the body absorbs more nitrogen, for the amount going into solution in the blood passing through the lungs is proportional to the increase in pressure. From the blood the gas diffuses to all of the tissues, and they slowly become saturated with the gas at the partial pressure attained in the blood. The rate at which the gas can be absorbed is, however, limited to the rate at which it can enter the blood, and it takes many hours for the whole of the body to become saturated with nitrogen at a new pressure of this gas. The times required to reach full saturation for all pressures are approximately the same, but the total amount which will finally be absorbed in each case is proportional to the pressure. That is, it takes an equal length of time to become readjusted to the nitrogen at two atmospheres and at four atmospheres above the pressure of nitrogen in the air, but at the end the body will contain twice as much nitrogen in the latter case. The time of exposure, as well as the pressure, is therefore important in determining the amount of nitrogen absorbed. The greater the amount absorbed, other things being equal, the greater is the likelihood of caisson disease developing.

The absorption of nitrogen is not in itself detrimental, and no symptoms develop from it during the stay in compressed air. When the man returns to normal pressure, the excess of nitrogen which has been absorbed is eliminated through the lungs. Since the absorbed nitrogen can only be eliminated from the tissues by passage into the blood, its removal is slow. If the decompression is rapid the blood and tissues remain more or less supersaturated with nitrogen, and the gas may separate as bubbles. If these bubbles are formed in the blood they tend to block the circulation; if formed about the nerves, as is frequently the case,

pain and paralysis follow. The opening of a bottle of soda water illustrates the separation of gas bubbles from a liquid in which gas has previously been held at a high pressure.

Treatment of Caisson Disease.

Caisson disease is treated by recompressing the man sufficiently to cause the separated nitrogen to redissolve in his blood and tissues. The ease with which this reabsorption can be effected depends upon the size of the bubbles which have separated; the smaller the bubbles the more readily they redissolve. Therefore, the sooner the treatment is applied the more likely is it to give relief. Recompression chambers or medical air locks are part of the equipment necessary for deep diving and caisson work. At the appearance of the first symptoms of the impending disease the man is placed in one of these large steel chambers, which is at once sealed, and compressed air is admitted up to approximately the pressure at which the man has been working. The pressure is afterward allowed to fall very slowly.

The prevention of caisson disease consists in decompression at such a rate as to prevent the formation of nitrogen bubbles in the blood. There are two methods by which this may be accomplished: continuous decompression and stage decompression. The first consists of a uniform diminution of the pressure starting at that to which the man has been exposed and ending at atmospheric pressure. The time consumed in the drop of pressure depends upon the initial pressure and the length of exposure. In stage decompression the pressure is not lowered uniformly, but in steps. These steps are so regulated that the supersaturation of the nitrogen in the blood is kept below, but not too far below, the point of bubble formation. Men rarely, if ever, become fully saturated with nitrogen to the pressure of the air in which they have been working. Therefore, during the first part of the continuous decompression they are absorbing and not eliminating nitrogen, while during the second half the difference of pressure in their tissues and that in the air may be dangerously great. It has been observed that it is safe for men who have worked at a pressure of two atmospheres, fifteen pounds gauge pressure, to pass immediately from this into a normal pressure. With reason-

able durations of exposure the same principle can be applied to any other pressures. Thus men who have worked in eight atmospheres can be dropped rapidly to four atmospheres without danger. After remaining at four atmospheres for a time the pressure is dropped by small steps until atmospheric pressure is reached. Caisson disease is very much less likely to develop after such stage decompression than after continuous decompression. Moreover, by the stage method the time required to reach atmospheric pressure is greatly shortened. The length of time that men may be exposed to various pressures of air and the manner and time of decompression are embodied in the laws of most of the states. Unfortunately, some states still require uniform decompression.

Poisoning by Oxygen.

Those who work under compressed air are exposed to a high partial pressure of oxygen as well as of nitrogen. The oxygen cannot separate in the blood as bubbles, as it is rapidly used by the tissues, nor, as is erroneously supposed, does the high partial pressure of oxygen cause the processes of life to quicken, like a fire. Instead, oxygen at high pressures is a poison not only to man, but to all forms of life. It is not, however, until the oxygen has reached more than three atmospheres, equivalent to an air pressure of fifteen atmospheres, that the symptoms of the poisonous and depressing action of the gas are immediately noted. Even at less pressures long exposure to oxygen may cause an inflammation of the lungs which is sometimes fatal. Cases of this sort are sometimes seen in divers who, through fouling of their line, have been forced to stay for long periods at great depths. The breathing of oxygen at a pressure of one atmosphere (*i.e.*, inhaling pure oxygen) has no detrimental effects unless the exposure is exceedingly long, a matter of days. There is no danger of oxygen poisoning in the use of the rescue apparatus employed for a few hours at a time by firemen and miners, in which an artificial atmosphere is supplied from a tank of oxygen carried on the back.

CHAPTER IX

THE LUNGS AND THEIR PROTECTION; ALSO DUST AND TUBERCULOSIS

Structure of the Lungs.

The lungs are composed of a great number of minute sacs, or saccules, which are the terminal dilatations of very small air tubes called bronchioles. Each saccule is divided by delicate partitions into many compartments, which are the ultimate air spaces

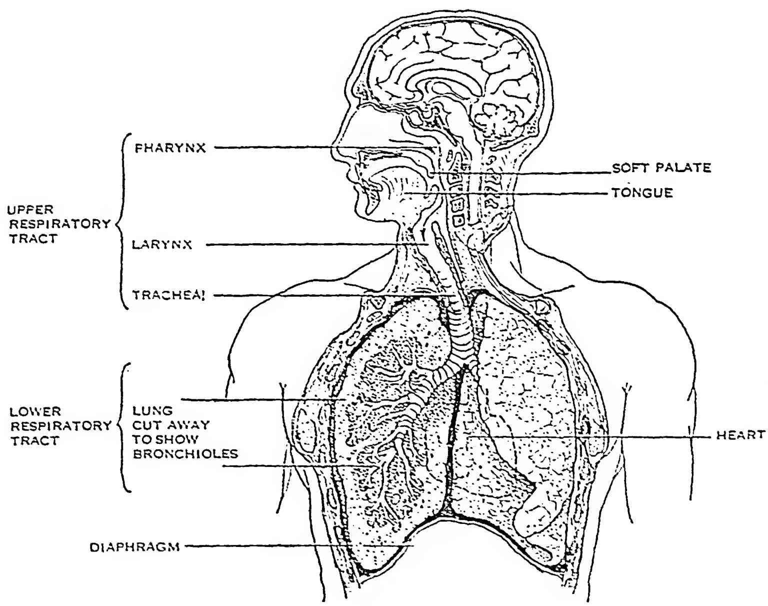

Figure 23. RESPIRATORY TRACT.

or alveoli. The bronchioles leading to the saccules are the branches of the bronchial tubes which spread out through the lungs. Fifty, a hundred, or even more of these bronchioles unite in a common tube, a bronchus. A bronchus with its bronchioles and air saccules is inclosed in a layer of connective tissue. The small mass thus inclosed, from which emerges only the bronchus and blood vessels running to the air sacs, is called a lobule. A

lobule with all its detailed structure is only about 0.5 centimeter in diameter.

The lungs are aggregations of lobules. The bronchi communicating with these lobules unite into tubes of increasing size; at the medial surface of the lungs and directly behind the heart these tubes open into the trachea, or windpipe. This tube with its walls stiffened by incomplete rings of cartilage extends upward and terminates in the pharynx, or throat. There is free access for atmospheric air to the lungs through the nose and mouth, except momentarily when the glottis is closed during the act of swallowing or coughing. The smaller bronchial tubes are provided with muscular walls and under irritation, or as the result of the disease asthma, may contract and prevent the passage of air into the area of saccules supplied by them. The trachea, bronchi, and bronchioles are lined with mucous membrane which secretes a mucous fluid upon its surface. The entire system of tubes takes very little part in the exchange of gases; it merely affords passage to and from the terminal air sacs.

Flow of Blood Through the Lungs.

The saccules and their alveoli have exceedingly thin walls of delicate elastic framework, almost completely filled with a network of capillary blood vessels and covered only by an extremely thin membrane. It is between the blood in these vessels and the air in the alveoli that gaseous exchange takes place. Owing to the thinness of the walls and the enormous total surface of the capillaries (estimated at ninety square meters in the lungs of man), the process of diffusion of gases is so rapid that virtual equilibrium of partial pressure of every gas in the alveoli is almost instantly established between the blood in the capillaries and the air in the alveoli.

The blood is supplied to both lungs through arteries from the right heart, which enter alongside of the bronchi. These are the only arteries in the body which carry the partially deoxygenated blood returned from the tissues. From their point of entry into the lungs the arteries follow the bronchi, dividing and subdividing until they form the capillaries of the alveoli.

From the capillaries onward the blood vessels unite again into increasingly larger vessels. These pulmonary veins finally emerge near the point of entrance of the arteries and pass to the left side of the heart. These are the only veins in the body which carry fully oxygenated blood. (See Figure 14.)

Cavity of the Chest.

Each lung has normally but one attachment in the body, which is that formed on the medial surface where the bronchi join the

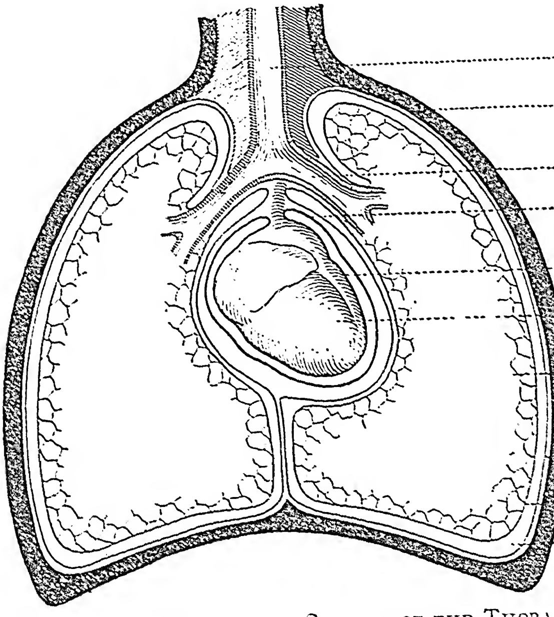

Figure 24. SCHEMA OF THE THORAX.

Showing the relations of the parietal and visceral layers of the pleural sacs and the layers of the pericardium. The pleural space is potential: the two layers of the pleura are in contact and rub during the movements of breathing.

trachea and the blood vessels enter. At all other points the lungs are freely movable within the chest cavity. This cavity is bounded behind by the spine and muscles of the back, on the sides by the ribs, and in front by the ribs and breastbone. It is closed below by the diaphragm, which is a thin muscular sheet attached at its edges to the walls of the chest at the lower ribs. The upper surface of the diaphragm is convex.

The lungs are extremely elastic. In a lung which has been

removed from the body the saccules contract until they are almost collapsed and contain only a small amount of air. In the body this collapse is prevented by the fact that the lungs are incased in the air-tight and comparatively rigid walled cavity of the chest. The lungs completely fill this cavity; there is no air in the potential space between the walls of the chest and the lungs, and only a little fluid by which the walls are moistened sufficiently for lubrication. Since the interior of the lungs is in communication with the outside air through the trachea, the elasticity of the saccules is overcome by the pressure of the atmosphere and the lungs are inflated and held tightly against the walls of the chest. By the same mechanism any movement of these walls, causing an increase or decrease of size in the cavity of the chest, results in a like change in the volume of the lungs, which are thus expanded or contracted in exact conformity to the size and shape of the chest cavity. As a result, air passes in and out of the air sacs and alveoli and through the trachea, thus producing the tidal movements of the air in and out of the nose and mouth.

The Pleura.

The surface of the lungs is covered by a thin layer of smooth tissue, the pleura. Similar tissue also lines the inner surface of the walls of the chest. The pleura resembles in appearance the peritoneum which lines the cavity of the abdomen and covers the intestines. The surface of the pleura covering the lungs and of that lining the chest are in contact, and slide over one another as the lungs expand and contract with the movements of the thorax. Inflammation of the pleura is known as pleurisy. If the inflammation is dry, the roughened surfaces rub together during the movements of breathing thus causing severe pain and a characteristic sound which can be heard by applying the ear to the chest wall. In other forms of infection the inflammation gives rise to fluid or pus which collects between the layers of the pleura and forces the lung away from the wall of the chest. The formation of pus under these circumstances is known as empyema.

If an opening is made in the wall of the chest, air enters,

the surfaces of the pleura are separated, and the lung collapses through its elasticity. If the opening remains the lung affected can no longer function, for the movements of the chest force air back and forth through the opening, instead of in and out through the windpipe. The layers of pleura which extend over the pericardial sac are attached to the back and front of the chest and to the diaphragm below, thus dividing the chest into two lateral compartments. The partition or mediastinum thus formed is sufficiently strong to withstand the elastic pull of the lungs; accordingly, if the opening in the chest wall enters only one pleural space the lung on the other side is not seriously affected and continues to function. A person may live after the collapse of one lung, but an opening into both sides of the chest, or double pneumothorax, as it is called, is immediately fatal. In the treatment of pulmonary tuberculosis the affected lung is sometimes collapsed by introducing air into one pleural space. The collapsed lung is thus given a rest. The air which surrounds the lung is gradually absorbed, or it may be withdrawn with a needle and syringe; the lung is thus brought back to its normal position and again assumes it function.

Movements of Breathing.

Changes in the volume of air in the lungs are brought about by movements of the diaphragm and ribs. Contraction of the diaphragm increases the length or height of the cavity of the chest, while an upward movement of the ribs, owing to the direction in which they are hinged on the spine, increases the cross-section of the chest, especially transversely. Inspiration is due to contraction of the diaphragm and of muscles attached to the ribs. These contractions are induced by nervous impulses. Expiration is a less active process than inspiration, for when the muscles relax the elasticity of the lungs themselves tends to drive out the air previously inhaled. This action is assisted by the twist or torque of the elastic ends of the ribs at their attachment to the breastbone, by the weight of the thorax in standing, and by the weight of the liver and other viscera upon the diaphragm when the person is lying upon his back. Any impediment to breathing due to pressure or constric-

tion in the respiratory passages is especially noticeable during expiration, because it is ordinarily of a passive character, a mere elastic recoil from inspiration. When the volume of breathing is increased by physical exercise many accessory muscles are called into action to assist in producing a deeper inspiration. Expiration also involves, then, a vigorous action on the part of the abdominal muscles.

Volume of Air in the Lungs.

A grown person of ordinary size, after making the deepest possible inspiration, can expire three to five liters of air; this is known as the vital capacity. The air moved at a single breath in normal breathing is known as the tidal air. Even in the most violent exertion it never reaches the vital capacity. The breathing during rest is from five to ten liters of air per minute; the number of breaths taken in the same time is on the average ten to twenty. The tidal air is thus approximately half a liter. During exertion both the rate and volume of breathing increase, but the rate less rapidly than the volume. Thus only a fraction of the capacity of the lungs is called into play during quiet breathing. After an inspiration of the average depth it is still possible to draw into the lungs a considerable quantity of air; this volume is from 1.25 to 2.25 liters and is known as the "complementary" air. At the end of an average expiration a further volume of air can with an effort be breathed out. This is known as the supplementary air and its volume is approximately equal to the complementary air. In quiet breathing the tidal air occupies the mid-position in the range of the respiratory movements. If breathing is increased, as it is during and after muscular exertion, the greater tidal air encroaches first upon the complementary air. Although the movements of respiration are greater, the chest still comes to rest at the position occupied at the end of a normal expiration. With further increase in the volume of breathing the supplementary air is utilized and the muscles of active expiration are called into play. During very rigorous muscular activity most of the complementary and some of the supplementary air are used at each breath. The utilization of the complementary in preference to the supplementary

air tends to maintain a larger volume of air constantly in the chest; it thus decreases the fluctuations in the concentrations of oxygen and carbon dioxide.

Nervous Control of Breathing.

Unlike the heart, the muscles of breathing have no independent or automatic rhythm. They contract only in response to impulses which travel from the medulla down the spinal cord and then by way of motor nerves to the muscles. These impulses arise and are coördinated in a specialized area in the brain, the respiratory center, which is in the medulla. The medulla is at the base of the brain and appears as a bulbous continuation of the spinal cord within the skull. The respiratory center has the function of adjusting the volume of air breathed so as to maintain a uniform alkalinity of the blood, under the influence of the vagus nerves; the center effects the reciprocal alternation of inspiration and expiration.

The activity of the respiratory center is influenced by the slight variations in the alkalinity of the arterial blood arising from the variations in the production of carbon dioxide (see Chapter VIII). When the alkalinity is diminished the center sends out stronger impulses, so that the depth of breathing is increased; at the same time each movement is made larger and more rapid, so that the volume of the tidal air is increased. The augmented volume of breathing tends to restore and maintain the alkalinity of the blood at its proper level. When the alkalinity is diminished, the center ceases sending out impulses, until the normal level of alkalinity is restored by the accumulation of carbon dioxide in the lungs and blood.

If undisturbed by influences which modify its action, the center sends out impulses in perfect rhythm; breathing is then regular, as it is in a sleeping man. On the other hand, in talking, singing, coughing, or sneezing, the normal rhythm is interrupted by impulses which arise in the higher or cerebral centers of the brain, or in reflexes from the internal organs, or are excited in the skin by external conditions. Nevertheless, the respiratory center compensates for the interruption by a greater or less ac-

tivity during the period immediately following. If the breath is held for a minute, there is breathed during the following minute or two an additional volume of air equal to that which would normally have been breathed during the time the breath was held. If the volume of breathing is voluntarily doubled for a minute, it is involuntarily decreased by an equal volume during the following minutes. The respiratory center is tolerant only to a limited extent toward these interferences with its action; for if the breath is held until considerable carbon dioxide has accumulated, the center breaks away from voluntary control and the breath can no longer be held. For a similar reason it is impossible to sing or talk connectedly during or immediately after exertion. The increased carbon dioxide production then greatly shortens the time required for the carbon dioxide in the lungs to accumulate up to the level at which the center refuses to submit to voluntary control.

The movements of breathing are reciprocating—that is, back and forth like the movement of the piston of a steam engine. Such movements as walking, in which the legs are swung back and forth, and the wagging of a dog's tail, are also examples of reciprocating movements. The physiological mechanism of such movements always includes two antagonistic sets of muscles tending to move the part in opposite directions, as in inspiration and expiration. For the mechanism to act it is necessary that one of the sets of muscles shall relax while the other contracts, and then that the first shall contract while the latter relaxes. The relaxation is as essential as the contraction, and the accurate timing of the alternation is essential for rhythm and efficiency. The rhythm and reciprocating action of breathing are usually entirely involuntary. The rhythm continues automatically so long as any excitation flows into the respiratory center. Besides the nerves sending impulses to the muscles from the respiratory center, there are also nerves which carry impulses from the lungs to the center. The most important of these are the two vagus nerves, one in each side of the neck. When an inspiration has occurred and the lungs are stretched, the endings of the vagal nerves in the lungs are stimulated, as

are also endings of nerves in the muscle of breathing, so that impulses are transmitted to the respiratory center. There they inhibit the inspiratory action and induce expiration. Conversely, the partial deflation of the lungs by expiration induces inspiration. The reversal of phase is carried out at the point which gives the proper volume of breathing as determined by the influence of the alkalinity of the blood upon the activity of the respiratory center.

Special Forms of Respiratory Movement.

In addition to breathing there are several special forms of respiratory movement among which may be mentioned coughing, sneezing, laughing, crying, sobbing, yawning, and hiccoughing. Each of these acts is largely reflex and involves the exact coördination of several structures. Most of the movements are controlled by separate groups of nerve cells and connections in the brain near the respiratory center. When these special centers are aroused, they supersede the ordinary action of the respiratory center, and initiate their characteristic form of respiratory movement.

Coughing.

Coughing tends to remove foreign substances from the respiratory passages. It is initiated by irritation of these passages, particularly the larynx. The irritation caused by a foreign body, phlegm, for example, sends an impulse to the cells controlling the coughing reflex. Impulses are radiated through the ordinary respiratory nerves to the muscles of breathing; a characteristic pattern of activity results, the act of coughing. There is first an inspiration, followed immediately by closing of the glottis, and then an expiration so that the pressure of air within the lungs is greatly increased. The glottis is then suddenly opened, and the air rushes out with explosive force. Simultaneously, the passage of the nose is closed off by the soft palate, so that any material which is driven out of the air passages passes through the mouth instead of the nose. The greatest velocity of the air is attained in the trachea and larger air passages. Consequently, coughing is most effective in removing sputum or

foreign bodies from those regions. Even repeated coughing may fail to remove sputum from the more remote air passages, particularly if it plugs these passages and prevents the entrance of air during the inspiration which precedes each cough.

Coughing is a protective reaction, and its failure may be attended with a greatly increased danger of pulmonary infection. During anesthesia or deep alcoholic intoxication, the reflex is lost, and these conditions may be followed by aspiration pneumonia, that is infection of the lungs caused by the passage of material down the trachea. In prolonged bronchitis, in advanced tuberculosis, and in the pneumonia of old and debilitated patients, the ineffective coughing results in a distinct increase in danger from the disease. When the upper respiratory passages are inflamed and there is little formation of phlegm, the continued coughing caused by the inflammation serves no purpose.

Coughing, however, is in some instances attended with dangers of its own. It puts a strain on the tissue of the lungs in the unprotected portions, especially at the tips which extend above the collar-bone. The resulting distention may be a contributing factor in the formation of a chronic dilatation known as "emphysema." The blood pressure is raised during coughing and hemorrhages may occur in the brain or elsewhere.

Sneezing.

The act of sneezing is much like coughing; the soft palate, however, does not close off the passage into the nose, so that the out-rushing air goes through both mouth and nose. Sneezing tends to remove substances which irritate the mucous membrane lining the nasal passages. The impulses which occasion the reflex act of sneezing originate in these passages and to a less extent in other organs such as the eyes; for looking at a brilliant light may also induce sneezing. The sneezing which follows exposure of the skin to chill or a draft arises only indirectly from the skin irritation, but directly from the nose. The chilling of the skin causes a dilatation of the blood vessels in the spongy tissue in the nasal passages and the consequent swelling may induce sneezing.

Laughing.

Laughing is an act similar to coughing. The glottis is only closed lightly, however, and the comparatively weak expiratory blasts occur in a rapid series. The distinction between laughing and crying is largely in the accompanying facial expressions. Sighing consists of a deep inspiration followed by a prolonged expiration. Sobbing is distinguished from sighing only by the greater velocity of the inspiratory act, and it is usually accompanied by a spasmodic approximation of the vocal cords. Laughing, crying, and sobbing are the accompaniments of mental states, but they are, nevertheless, as much reflexes as is coughing. The origin of the stimuli for the act is in the brain instead of the respiratory passages. Moreover, coughing may also arise in the same manner either voluntarily or as a result of an unconscious imitation of others who have coughed in the same vicinity, as occurs in church or during dull lectures. Yawning is a deep inspiration with the glottis wide open, and as a rule with the mouth also open; simultaneously, other muscles contract and stretch their antagonists also. The significance of yawning is not understood; it has been suggested that it is due to a momentarily sluggish circulation in the brain. A yawn resembles the gasps occurring in asphyxia or hemorrhage.

Hiccough.

Hiccoughing is nearly the reverse of coughing. The diaphragm is suddenly contracted and at the same time the glottis closed on the air which is being rapidly inspired. The irritation which occasions the act may arise from inflammation of the abdominal organs, from irritation of the diaphragm due to swallowing hot food or drink, or from pressure in the stomach distended with food or gas. Hiccoughing may also have its origin in nervousness or may arise from undiscoverable causes. The condition is annoying, serves no apparent purpose, and is often difficult to control. The milder forms may sometimes be checked by coughing or sneezing, by swallowing ice, salt, or vinegar, or cold water. Strongly pulling on the tongue at times gives immediate relief, and if this fails the attack may yield to the nausea caused by tickling the back of the throat. In rare instances hiccough-

ing may last for a week or longer and cause severe exhaustion. Large doses of morphine are then usually resorted to. Inhalation of 5 to 10 per cent of carbon dioxide by stimulating breathing may overcome it.

Protection of the Lungs.

The temperature of the air that we breathe varies widely—more than 100° F.—so also its moisture content. It generally contains also solid particles such as soot and bacteria, and sometimes such vapors as sulphur dioxide from burning coal and various fumes from automobiles and factories. The membrane of the air sacs and alveoli of the lungs is delicate and if anything except pure warm moist air is brought in contact with it serious damage results. The upper respiratory passages—the nose, throat, trachea, and larger bronchi—are less sensitive than the deeper structures. Irritation of the upper respiratory passages results at most in a sore throat or a head cold, but irritation of the alveoli and air sacs leads to the much more serious pneumonia.

The upper respiratory passages protect the lungs by warming the air to body temperature, saturating it with moisture, and removing by contact the greater part of the solid particles and irritating fumes.

The Nasal Passage.

The nasal passage consists of a rectangular chamber in the bones of the skull and forms a passage from the outside air into the pharynx. The hard palate which forms the roof of the mouth also forms the floor of the nasal passage. Above this passage are bones at the base of the skull. A central septum divides the passage longitudinally.

The forward end of the nasal passage is covered by the nose, which serves as a guard to the inner passage. From the side walls of the nasal passage three scroll-shaped bones project. These are the turbinate bones. They are surrounded by soft spongy tissue containing many blood vessels. The turbinate bones serve to increase the surface which is exposed to the air entering the nose.

Protection Against Dust.

The nasal passage is lined with mucous membrane containing numerous minute glands which secrete mucus. It differs from most mucous membranes in that it is covered with cilia.

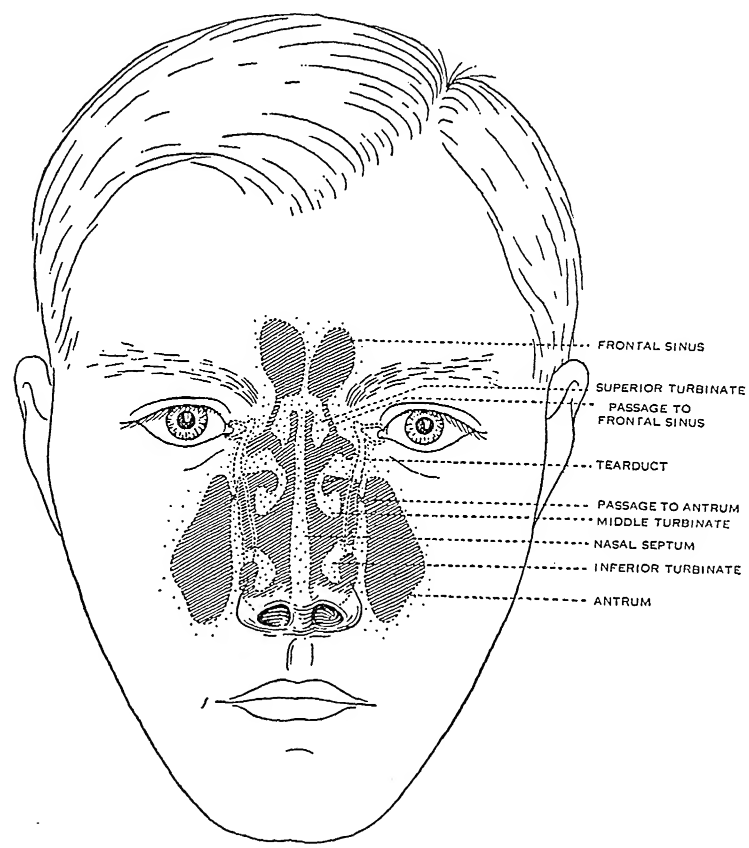

Figure 25. NASAL PASSAGE AND SINUSES.
The nasal passage is divided by the septum. The turbinate bones, covered with erectile tissue and mucous membrane, extend out from the lateral walls of the passage. The maxillary sinuses, or antrums, in the cheek bones, and the frontal sinuses in the bone of the forehead are lined with mucous membrane and are continuous with the nasal passage through small openings. The tear duct also opens into the nasal passage.

Cilia are hair-like projections so minute as to be invisible without the aid of a microscope. The cilia wave back and forth continually, slowly in one direction and rapidly in the opposite

direction. Dust particles which are caught upon the moist mucous membrane are slowly carried to the pharynx and swallowed. All of the upper respiratory passages are lined with cilia to remove dust, but the sharp bends made by the nasal passages, their narrowness, and the relatively large area thus exposed to the air make the nose the more effective in removing dust. This advantage is lost in breathing through the mouth. Foreign substances in amounts sufficient to irritate the respiratory passages cause sneezing and coughing and these respiratory acts assist in their removal.

Warming and Moistening the Air Breathed.

Air is warmed to body temperature and saturated with water vapor during its course through the nasal passages. Even when breathing through the mouth, the air, by the time it reaches the trachea, is usually both warm and moist unless the breathing is excessive. The fluid necessary to moisten the air comes from the secretion of the mucous glands in the membrane of the nose and from the saliva in the mouth. Breathing through the mouth results in the deposition of substances held in solution in the saliva and thus in the formation of "tartar."

Cold air is always relatively dry, for the partial pressure of water vapor falls with the temperature. Thus at 0°C. (32°F.) one cubic meter of air saturated with moisture contains 5 grams of water; but at body temperature, 38° C. (99° F.), the same amount of air saturated with moisture contains 50 grams. A man, even at rest, breathes a cubic meter of air (1,000 liters) in less than two hours. If the air is at 0°C. there is added during this time 45 grams (1.5 ounces) of water from the nasal passages, or more than a pint in twenty-four hours. The evaporation of water requires heat and under most circumstances much more heat is used to moisten than to warm the air passing through the nose. Only 8 kilocalories (30 B.T.U.) are necessary to raise the temperature of 1 cubic meter of air from 0°C. to body temperature, but 26 kilocalories (100 B.T.U.) in addition are consumed by the latent heat of evaporation of the water necessary to moisten it.

In the artificial heating of buildings the air is not usually humidified. The heated air is, therefore, very dry, for it contains no more water than air at the prevailing outside temperature. If the room is heated to 20° C. (72° F.) and the air is drawn from outside at a temperature of 0° C. (32° F.), as much moisture is needed from the nasal passages and nearly as much heat, as if the cold outside air were breathed. The drying effect upon the mucous membrane of the nose is even greater in the warm room than in the outside air. Cold air acting upon the nasal passages stimulates the flow of mucus. This stimulation is lacking in the warm air of the room, which may cause irritation and congestion of the nasal passage, and thus be productive of head colds. When the heated air of the room is humidified to approximately 75 per cent, the temperature can, with comfort, be decreased several degrees, for instance from 72° to 65° F. In this there is, however, no saving in fuel; in fact, somewhat more is required even at the lower temperature, for heat is used in evaporating water to humidify the air. The advantages are greater comfort and freedom from nasal irritation.

Erectile Tissues of the Nose.

The tissue about the turbinate bones is of peculiar structure; it is known as erectile tissue. The blood from the arteries, instead of passing into capillary vessels, runs into cavernous spaces which empty directly into veins. The pressure of the blood within these spaces is determined by the rate of flow through them. Ordinarily the pressure is slight and the spaces are flattened. When the arteries dilate, the spaces distend; an erection occurs. The degree of distention is also regulated by the tone or firmness of the muscular tissue in the walls of the spaces. Normally the blood flow may be increased without marked swelling of the tissue, for the tone of the walls of the spaces is also increased. The greater the flow of blood, the more heat is made available for warming and humidifying the air entering the nose. If, however, the arteries dilate and the walls of the space remain flabby, congestion results, and sufficient erection of the tissue occurs to cause a partial blocking of the nasal passages. This congestion

is not normal, for ordinarily such influences as cold air, which increase the blood flow, also increase the tone of the walls of the vessels. The congestion furthers the development of infections and catarrhal conditions in the nasal passage. The congestion may be produced by a chilling of the skin, and by a draft on the back of the neck, as well as by any irritation in the nose such as infection or the warm dry air of heated rooms. The breathing of cold air increases the tone of the vessels, and the congestion may be relieved on going out-of-doors; but it returns on coming into the heated room again. Vigorous blowing of the nose compresses the vessels and affords a brief period of relief from the obstruction; this occurs also in the act of sneezing.

The Sinuses.

There are cavities in the bones of the forehead—the frontal sinuses; in the bones of the cheeks—the maxillary sinuses or antrums; and in the base of the skull—the sphenoid and ethmoid sinuses. These sinuses are lined with mucous membrane which is a continuation of that in the nose. The sinuses communicate with the nose through small passages, which allow an equalization of the air pressure within the sinuses, just as the eustachian tube does for the middle ear. The sinuses are less exposed, and therefore less readily infected, than the rest of the nasal passages. Nevertheless, they do at times become infected from the nose; a severe head cold may extend into one or more of the sinuses and cause an inflammation. The sinusitis which results is much more painful and serious than an inflammation in the more open nasal passages. The communicating channel to the nose frequently becomes closed by the swelling, pus is dammed back under pressure, and the infection may corrode its way through the tissues into the eyes or brain. Even when the passages are not closed, the drainage of pus from the sinuses is very poor; this is particularly true of the maxillary sinus, for its opening into the nose is near the top of the sinus. The retention of infected material in the sinuses results in a chronic inflammation, which rarely subsides until a passage for drainage has been made by a surgical operation.

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direction. Dust particles which are caught upon the moist mucous membrane are slowly carried to the pharynx and swallowed. All of the upper respiratory passages are lined with cilia to remove dust, but the sharp bends made by the nasal passages, their narrowness, and the relatively large area thus exposed to the air make the nose the more effective in removing dust. This advantage is lost in breathing through the mouth. Foreign substances in amounts sufficient to irritate the respiratory passages cause sneezing and coughing and these respiratory acts assist in their removal.

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Dust.

A certain amount of dust is a normal and important constituent of the atmosphere; it serves to limit the humidity of the air by precipitating moisture as rain. Without dust there would be no rain and no clouds or mists. Instead, the moisture of the humid air would condense as dew on all surfaces with which it came in contact. What may be spoken of as the "normal" dust consists of mineral matter from the soil, volcanic ash, carbon, interplanetary particles, and salt from sea spray. Organic materials are also present in dust, although to a limited extent, and consist of dry particles blown into the air from disintegrating animal and vegetable matter, seeds, scales of the skin, pollen, fragments of hair, yeasts, molds, spores, and bacteria. There is more dust in the air of cities than in the country, and usually more dust in houses than in the outside air; the use of vacuum cleaners has reduced the indoor dust.

Aside from the bacteria in dust, ordinary amounts of dust are not injurious. It is largely separated from the air by the upper respiratory tract and does not reach the lungs; the small quantity which does reach them is not usually of a nature to cause irritation. In many occupations, however, the air is contaminated by large quantities of dust; and in some it is of an extremely injurious character, causing serious damage to the lungs and resulting in the condition known as fibrosis. Fibrosis predisposes to pneumonia and tuberculosis. A high incidence of tuberculosis, and other respiratory diseases among the workmen in any particular occupation, is an almost certain indication that the occupation is one involving (as there practiced) the inhalation of injurious dust.

Dust as a Cause of Pulmonary Disease.

The association of certain kinds of dust and tuberculosis has been known for a long time. A particularly striking instance is given in the wording of a patent granted in 1713 to Thomas Benson of England for the working of flint by a wet method. Previously the flints were broken dry, producing dust and, as the patent states, this dry process "proved very destructive to mankind inasmuch as any person, ever so healthful and strong, work-

ing in that business cannot possibly survive over two years, occasioned by the dust sucked into his body by the air he breathes." The gruesome names "potter's rot" and "grinder's rot," given to the lung diseases common in these occupations, serve to emphasize the danger to health caused by dust.

Not all dusts are equally harmful; workers in some very dusty trades show no increase in pulmonary disease above that found in comparatively dustless trades. The damage from dust depends upon two factors: (1) the size of the dust particles; (2) their sharpness and chemical compositions.

Only the finer dust particles reach the lungs; the large and easily visible particles are removed by the nose. Air containing dangerous quantities of very fine dust may appear pure, while an atmosphere cloudy with coarse dust may merely cause irritation of the nose and throat without affecting the lungs. Therefore the amount of dust in the air, particularly its weight, is of much less importance than the size and nature of the dust particles. In a survey made to determine the amount of dust in the air, 225 milligrams per cubic meter of air were found in one cement factory, but the workmen did not show any increase above the average in pulmonary disease. On the other hand, an air sample taken in a gold mine in very hard quartz rock showed only 2.8 milligrams of dust per cubic meter of air, but of this dust 60 per cent was of a size which might reach the lungs. There were approximately 150,000,000 particles of harmful size per cubic meter. Many of the workers in this mine became tubercular.

In order to damage the lungs, the dust must not only be of such size as to reach the lungs, but must be of such nature as to injure the lung tissue either mechanically or chemically. The substance doing the greatest injury is silica. Coal dust, if it contains no silica from the rock surrounding the vein, does not damage the lungs; nor do other fine organic dusts such as flour. Even organic dust may, however, contain silica. Dust arising from the opening, picking, and carding of cotton will in time cause pulmonary disease. So also may dust arising from the machining of hardwood such as boxwood and beech. The vegetable dusts do not as a rule lead directly to tuberculosis, but rather to pneumonia or to chronic bronchitis.

The dust from plaster of Paris, talc, slate, shale, iron ore, and limestone do not reach the lungs in appreciable quantities. On the other hand, such large quantities of coal dust may reach the lungs that they become black from the collected coal particles, yet among coal miners generally there is little tuberculosis. Although certain dusts do not lead directly to serious disease of the lungs, they should not, for that reason, be thought of as entirely harmless. Excessive amounts of any kind of dust are undesirable and may lead to irritation of the upper respiratory tract, catarrh, and an increased susceptibility to infection in this region. Persons with tuberculosis, asthma, or other diseases of the respiratory tract should not be allowed to work in a dusty atmosphere.

Poisoning from Dust.

In addition to the mechanical irritation caused by dusts, certain dusts may also cause poisoning. In such cases the damage is not exerted primarily upon the lungs. When poisonous substances are inhaled as dust they are separated from the air in the upper respiratory tract and swallowed. The material is then absorbed from the intestines and exerts its poisonous action upon the system. Thus lead poisoning may result from the dust (or condensed vapor) from metallic lead in the process of smelting, soldering, or melting, or during the oxidation of lead in the preparation of lead compounds as in the manufacture of paint, or even from the handling of the metal itself as in typesetting. The same is true of arsenic and its compounds, such as Paris green, and to a less extent of other metals such as molten brass, zinc, and manganese. The dust in sugar mills causes the teeth to decay. Dust containing compounds of chromium causes an ulceration of the septum of the nose, leading in some cases to perforation. Tobacco dust may cause a mild degree of nicotine poisoning; the dust from African boxwood likewise causes poisoning of the alkaloidal type. The pollen from various plants gives rise to hay fever, asthma, and related disorders in susceptible persons. Dust containing certain types of bacteria may give rise to specific infections. The anthrax bacilli carried in dust arising from wool or rags may cause infection of the skin, sometimes also of

the lungs; it gives rise to "malignant pustule" or to "ragpicker's" or "woolsorter's" disease, which is often fatal (see Chapter XII).

Silicosis.

When dust causes an inflammation of the mucous membrane of the respiratory tract or of the lungs, the condition is called in general pneumokoniosis. The term is modified according to the various kinds of dusts. Thus anthracosis is caused by some kinds of coal dust; siderosis by iron and steel dust; bysinosis by vegetable fiber dust; and silicosis by stone or silica dust. Silicosis deserves especial consideration because of its importance in predisposing to pulmonary tuberculosis.

Silica occurs in the dust from quartz, granite, flint, and sandstone. The dust from a grindstone made of sandstone is much more harmful than that from a wheel of emery or carborundum. The onset of silicosis is gradual. In early silicosis the general health remains good, although there may be some shortness of breath on exertion and recurrent bronchial "colds." Later a cough develops which is most marked in the morning but gives rise to little expectoration. At this stage there may be impairment in working capacity; the expansion of the chest is much decreased and there is marked shortness of breath.

The fibrosis caused by silica consists in the formation of minute scars over the points injured by the sharp particles. If the exposure continues the scars replace more and more of the lung tissue, distorting it and rendering it unsuited for its function of aërating the blood. The injured lung is readily susceptible to infection, so that bronchitis, pneumonia, and pleurisy are common. The most frequent sequel, however, is a tubercular infection in the damaged lungs, and the disease then runs a rapidly fatal course.

Dust stands first as the cause of industrial consumption. The writer Agricola long ago made the observation that miners in the Carpathian Mountains suffered so severely from the dust in their occupation that women could be found who had married as many as seven husbands. The following table gives the death rate from tuberculosis per million in various dusty occupations, and emphasizes the importance of silica dust as predisposing to

this disease which formerly was called the "captain among the men of death."

TABLE V

MORTALITY FROM TUBERCULOSIS IN VARIOUS TRADES

Occupation	Mortality per million
Brickmakers (building bricks)	900
Coal miners	1,000
Limestone workers	1,400
Iron-ore miners	1,800
All males (England and Wales) fifteen years and over	2,100
Potters	3,100
Lead miners	3,900
Cutlers	5,900
Granite cutters	6,200
Gold miners (Transvaal)	13,800
Metal grinders	15,200
Sandstone workers	16,700
Ganister workers	22,300
Flint knappers	41,000

Prevention of Excessive Dust.

There are three chief methods available for the avoidance of the inhalation of dust: (1) prevention of the formation of dust; (2) prevention of the escape of dust into the air; and (3) removal of the dust from the air. The choice of the particular method to be used to prevent the inhalation of dust depends upon the circumstances of the occupation. Whichever is adopted, no workman should ever be exposed directly to air contaminated with an excessive amount of any kind of dust or to any dust containing appreciable amounts of silica or poisonous metallic substances.

In many instances the formation of dust can be minimized by the application of water, oil, or steam. The sprinkling of dusty streets with water is an example of this means of preventing dust formation; the splitting of flints by a wet method, as instanced above in the early patent of Thomas Benson, is an application of

the same principle. Water may be used to prevent dust from arising in rock drilling, mining, stone crushing, and in the grinding of metals. Wet methods have also been adopted with advantage in the lead and pottery industries and in sandpapering paint.

When dust formation cannot be prevented, its escape may be limited by inclosing its source. Dust-proof coverings can be made for packing or conveying dusty materials, especially when it is of poisonous nature, as in the mixing and boxing of lead pigments. Stone crushing, clay grinding, and similar procedures can be carried out in inclosed machinery. Closed conveyors may be substituted for the open type.

In certain instances in which the use of inclosed machinery is impossible, it is necessary to remove the dust by a current of air. This is done by means of exhaust ventilation. The dust must be removed as near as possible to its point of origin; it is thus prevented from getting into the general atmosphere and a smaller volume of air is necessary to remove it. The air current from the source of dust to the exhaust pipe opening should envelop the dust and be of sufficient velocity to carry the dust in spite of the drafts existing in the room. Since dust tends to fall, it is usually best to remove it in a downward direction. When an exhaust system is used for removing dust, provision should be made for a corresponding inlet to afford ventilation to the room, and in winter this air should be heated. In exhausting dusty air from several dust-producing machines, there may be a single main duct connected with a fan and with branch ducts to each machine. If such an arrangement of ducts is not properly designed and the amount of air passing into the different openings is not the same, the current is weak in some and strong in others. Sharp bends at the point where the side ducts meet the main duct are particularly to be avoided; air currents do not turn corners easily.

In some installations of large machinery it is feasible to provide forced ventilation for the entire room in which the machine is installed. The air inlet is placed above the operator's head and to the rear; a suction fan is placed on the opposite side of the machine, near the floor, and draws the air down and away from the operator.

The dust collected by exhaust systems should not be discharged

into the surrounding atmosphere. It may be extracted in towers equipped with water sprays or restrained by filters of cheese-cloth. In some cases—cement factories for instance—the deposition of the dust in stacks by a high-tension current of electricity, the Cottrell method, is very effective, and saves a valuable by-product.

In some procedures it is impossible to keep the atmosphere free from excessive dust by any of the methods outlined above. In these cases respirators or dust helmets should be worn. A respirator consists of a filter of fabric, held on a frame and fastened over the mouth and nose. The air breathed is filtered through the fabric. If the dust particles are small such respirators are as a rule inefficient for no fabric fine enough to breathe through will remove this dust. Respirators frequently fit poorly upon the face and are hot and uncomfortable. A dust helmet is better. It consists of a light box fitted loosely over the head, with a window, usually of fine-mesh wire, in front of the eyes. Compressed air is admitted by a hose attached to the top of the helmet and the air escapes freely from the helmet. A flow of approximately three cubic feet per minute is adequate. An operator equipped with such a dust helmet may work in safety regardless of the dust contamination in the surrounding air. The method is limited by the air hose and can only be used for relatively stationary operations such as sandblasting.

Tuberculosis.

Tuberculosis is the name given to the disease caused by the bacillus tuberculosis. Although the disease is a very ancient one, the bacillus which causes it was not discovered until 1882. The discoverer was Dr. Robert Koch of the University of Berlin. The name of the disease is derived from the nature of the change occurring in the tissues upon which the bacilli grow. There are produced nodules, or small lumps, called tubercles, in which the bacilli are established. Ultimately they may be filled with a soft cheesy material, or they may ulcerate and become open sores. If they heal, a scar is formed in which lime salts are sometimes deposited. In distinction from the inflammation caused by other local infections—a boil, for example—the growth of the tubercle

bacillus produces no pus nor does it usually cause pain; a tubercular abscess is said to be "cold."

The bacillus may infect any organ or structure in the body. Thus there may be tuberculosis of the skin, called "lupus"; tuberculosis of the bones, which gives rise to such deformity as hunchback; tuberculosis of the lymph glands, especially in the neck, called "scrofula," which is relatively common in children; and tuberculosis of such internal organs as the spleen, liver, or kidney. The most common seat of infection is the lungs, giving rise to pulmonary tuberculosis, formerly called consumption, or phthisis.

Tuberculosis affects animals as well as men. Cold-blooded animals, and also cats, dogs, horses, and sheep, are seldom affected; but the disease is common in birds, and particularly in cattle. There are minor differences between the bacilli which affect cattle and those which affect man. Man cannot acquire the disease from birds, but children may be infected from the milk of diseased cows. Bovine tuberculosis transmitted through the milk rarely induces pulmonary tuberculosis; it is responsible, however, for many of the cases of tuberculosis of other organs; the bacteria probably enter by way of the tonsils. Some towns and states now require by law that all milk sold shall either be pasteurized or supplied from cattle shown by periodic tests to be free from tuberculosis. Pasteurization consists in heating the milk, preferably after bottling, for a short time at a temperature a little below the boiling point. When properly performed, pasteurization destroys not only the organisms of tuberculosis, but also those of typhoid fever, scarlet fever, diphtheria, and foot-and-mouth disease as well. The lactic-acid bacilli are not destroyed, however, so that pasteurized milk sours as readily as raw milk.

The name consumption, or phthisis, is given to tuberculosis of the lungs. There are two forms of the disease—acute and chronic; the first is "galloping consumption," the latter is the common and more prolonged type. Galloping consumption resembles pneumonia, for which it is usually mistaken at first. The disease starts abruptly with high fever and prostration; death

may occur within two weeks to three months or occasionally the disease may slacken and assume the chronic form.

The great majority of cases of consumption are of the chronic type. The infection nearly always starts in the upper portion, or apex, of the lungs, and as it progresses it descends, spreading throughout the lungs. If the destruction is extensive, cavities may be formed in the lungs. In more favorable instances a firm wall of scar tissue is formed about the diseased area and separates it from the rest of the lungs. This walling off of the infected portion is the healing process in tuberculosis; the disease, however, is not cured. It merely becomes latent. The bacilli may be retained for years in these "healed" areas, and under suitable conditions may reëstablish the active disease. The sputum from all active cases of consumption contains tubercle bacilli, sometimes in tremendous numbers, and it is by this means that the disease is spread.

The onset of consumption is usually gradual and shows no striking peculiarities by which it may be readily recognized. Early diagnosis is, therefore, difficult, but it is of extreme importance, for the earlier the treatment is started the more likely it is to be successful.

Symptoms of Tuberculosis.

Consumption usually starts with a "neglected cold" or bronchitis. The condition does not clear up readily and a persistent cough develops. This cough is one of the earliest symptoms of consumption and is present in the majority of cases from beginning to end. At first the cough is dry and hacking, but subsequently it becomes looser and is associated with a yellowish expectoration. At times this expectoration may be bloodstained or blood itself may be expectorated. Hemorrhage of this type sometimes occurs in apparently healthy persons and may be the first indication of consumption. There is, as a rule, no pain in the diseased lungs although painful pleurisy may develop.

The constitutional and debilitating symptoms of consumption arise from the absorption into the blood of poisonous products from the infected area. As the disease progresses there is loss of weight. It is this emaciation which gives to the disease the

name consumption. The loss is most rapid early in the disease and may even amount to five or six pounds a week. Gain or loss of weight is one of the best indications of the checking or development of the disease. Since most cases of tuberculosis occur before forty years of age, emphasis is now placed on maintaining in persons who are threatened with tuberculosis a normal weight or even somewhat greater than normal weight until this time of life. After forty, however, and contrary to the general tendency, the weight should be brought back to normal or slightly below, thus retarding the development of other chronic diseases which come with age.

A continual low fever is one of the symptoms of consumption. In the early part of the disease it is not marked, but a rise of temperature may result from trivial causes such as slight exertion or excitement, which would not affect a normal person. The fever of early tuberculosis often brings a sharply defined spot of color over the cheekbone. This hectic flush, together with the otherwise pale skin, moist and dilated eyes, the delicate slender form and languid manner, give a certain appealing beauty to young women with incipient tuberculosis. Artists have painted and poets have written of this evasive beauty. But within a short time, possibly hastened by the responsibilities of marriage, the young woman becomes an emaciated invalid. In fact, in both sexes marriage hastens death from tuberculosis.

Persons with consumption have a decreased capacity for work and are easily fatigued. They are often irritable, intolerant, and petulant, but are usually optimistic as to their future health. Unless the disease is checked, the strength gradually fails until death results or a hemorrhage cuts short the "decline."

Conditions Necessary for Development of Tuberculosis.

Two conditions are necessary for the development of tuberculosis—infection by the tubercle bacillus and a subnormal resistance to the infection. The bacilli are found wherever human beings are crowded together. It has been estimated that from one to four billions of the bacilli may be thrown off each twenty-four hours in the expectoration of a person with moderately advanced disease. The bacilli are transmitted from person to

person largely through "contact." Contact infection implies the mingling together of the sick and well, but does not necessarily mean actual touch. The transmission may be through objects of common use, such as pencils, water glasses, towels, or bed linen; it may also be through droplets sprayed into the air during coughing or talking, and inhaled by others; or it may be through dust containing dried sputum from the floor, contaminated food, or soiled fingers; or the bacilli may be carried by flies. So wide-spread are the bacilli that, in cities at least, probably no individual passes a week without being exposed to infection. From 60 to 90 per cent of all persons dying from diseases other than tuberculosis show in their lungs small areas where the infection has at one time developed and has been arrested. It is believed that the bacilli continue to live in these areas and that they may develop again actively at any time that the general health is impaired and thus produce consumption. From results with the tuberculin test (the skin reaction after injection of dead bacilli or an extract from them), it is estimated that 90 per cent of all children are infected before reaching the twelfth year.

Although the bacilli are almost universally present, only a minority of all persons develop obvious infection. The continual inoculation with the bacilli from childhood on, probably imparts a partial immunity to tuberculosis such as that developed against typhoid fever as the result of the injection of a vaccine of dead typhoid bacilli. Uncivilized peoples, when first encountering tuberculosis brought to them by explorers, do not have this partial immunity and even the healthy acquire the disease and die.

The larger and more continuous the dose of bacilli received, the more likely is the infection to develop. It has been shown in one survey that 79 per cent of the individuals fully exposed for a long time to open cases of consumption became infected. Only 28 per cent of those partially exposed or exposed for a short time became obviously infected. The percentage of infection from casual exposure such as everyone encounters is estimated at 8 per cent.

The human body is poor soil for the growth of the tubercle bacillus. The human adult in normal health is practically im-

mune to the average degree of infection. But no age is exempt; the disease is found in the baby and in the man of eighty, but is most common between the ages of eighteen and thirty-five. Under comparable conditions the influence of sex is very slight. The influence of race, however, is important. Consumption is a very prevalent and fatal disease among negroes and the Indians of North America. The Irish and Scandinavians are more prone to the disease than are other European races. Jews have a relatively low susceptibility.

Conditions Favoring Development of Tuberculosis.

Any condition which lowers the resistance of the body predisposes to tuberculosis. Dwellers in cities in dark, crowded tenement houses, workers in cellars and in poorly ventilated rooms, and persons addicted to alcohol are especially prone to the disease. An experiment performed by Trudeau shows clearly the relation of environment to the development of tuberculosis. He found that rabbits inoculated with the bacilli and then confined in dark damp places without sunlight and fresh air rapidly succumb, while other rabbits similarly inoculated, but allowed to run wild, did not develop the disease. The occupants of prisons, asylums, and too often of dark and ill-ventilated workshops, are in the position of Trudeau's first group of rabbits, for they work under conditions most favorable to the development of the bacilli which have lodged in their bodies.

Tuberculosis and Heredity.

Tuberculosis is not an hereditary disease; that is, the tubercle bacillus is not carried in either the ovum or the spermatozoon. In rare cases the disease may be transmitted through the blood stream of the mother to the placenta and so to the child but the chance of this occurring is very slight. Tuberculosis is primarily a local infection. It may, however, be carried from one part of the body to another, so that tuberculosis of the lungs may be complicated by tuberculosis developing, for instance, in the liver. Similarly, the tuberculosis in a diseased mother may, in rare instances, pass to the child in her uterus.

Although usually born healthy, the child of a tubercular mother

is more apt to develop the disease than is the child of a healthy mother. The contact between the mother and child is intimate, and the opportunity for a high degree of infection is very great. The same unhygienic conditions which may have lowered the resistance of the mother also act upon the child, or the low physical resistance which has predisposed the mother to the disease may be inherited by the child.

Tuberculosis and Industry.

Improvements in the standard of living and the general well-being of the community have lessened the death rate from tuberculosis. The disease no longer leads the list in mortality. There are conditions, however, in industrial life which counteract the benefits derived from the improved standard of living. This is shown by the comparative decrease in the mortality from tuberculosis in women and men. In 1851-60 the death rate in England from tuberculosis was 2,871 per million for women, and 2,668 for men; in 1913 the death rate from the disease was 848 for women and 1,178 for men. Furthermore, the preponderance of tuberculosis in men is especially marked between the ages of twenty-five and sixty-five, which is the working period of life. The mortality from forty-five to fifty-five years was, in 1912, 1,085 per million in women and 2,285 in men. Between these ages men are subject to twice as heavy mortality as are women, and tuberculosis accounts for nearly one-fifth of the total deaths among the men. Outside of industrial centers the death rates from tuberculosis for men and women are approximately the same. During the European war the employment of large numbers of female workers in munition plants was accompanied by a rise in mortality from tuberculosis among the women; this increase did not occur in nonindustrial towns.

Prevention of Industrial Tuberculosis.

There are two aspects of the prevention of tuberculosis: (1) the prevention of the dissemination of the bacilli and (2) the strengthening of the employees to resist the growth. The first requires the isolation or education of the consumptive; the second involves improved hygiene in the working places and an im-

proved standard of living for the worker and his family. These problems are largely economic and sociological rather than medical.

The consumptive becomes a menace to others only when his habits are bad. In a modern sanitarium for tuberculosis which may contain hundreds of advanced cases the infection is not spread. The air, dust, and objects of common contact are there free from the bacilli because the inmates are educated to the personal hygiene of their disease. A consumptive uneducated to the collection and disposal of his sputum, who coughs with his mouth unprotected, or who in any way allows the dissemination of infectious material is a menace to society and should be treated by compulsory isolation. Unfortunately, many consumptives are ignorant of their disease until it has reached the point of disability; and they may, in their ignorance, spread the infection to their families and associates. It is of the utmost importance that the consumptive should be recognized as early as possible. Such recognition cannot be obtained by requiring physicians to make notification to the civic health authorities, as is the case with infectious fevers, such as smallpox or scarlet fever. The consumptive may not consult a physician until he is in nearly the last stage of the disease, but for months or even years before this he may have actively spread the disease. Compulsory notification would lead many diseased persons to hesitate to consult a physician if they thought their disease was consumption, and this would retard rather than assist the early recognition of the disease. The consumptive tends to hide his disease from the knowledge of others; he may be sensitive of his condition, for many persons look upon tuberculosis with hysterical dread; or he may fear that he will lose his employment if his disease is recognized.

The proper management of the consumptive in industry requires close coöperation between the employer and the employee. Such coöperation can only be obtained through education. When the employee realizes that it is to his own advantage for his disease to be recognized at the earliest moment, then and then only will he coöperate. Consumption in its early stages does not necessarily require a great restriction in the employment, for

there is no lack of capability on the part of the employee. If the disease is recognized early he should usually be allowed to continue his employment, if this is of a character not directly deleterious to his condition. If it is deleterious he is warned in time and may improve his chance of recovery by seeking other employment. By early recognition of the disease, or better by recognition of the failing health and strength which usually precede the acute appearance of the disease, the employee can be led to take precautions in time. This can be accomplished by instruction in the rules of hygienic living, by a maximum of outdoor recreation, a plentiful supply of wholesome food, and long hours of sleep with fresh air in the room or preferably out-of-doors. If the employee does not conform to these instructions, he is a social and economic danger; his disease will inevitably advance, his capability will decrease, and he will spread infection among his fellow workmen.

The recognition of early tuberculosis is best accomplished by periodical medical examination of all employees, including office workers. The employee must be educated to realize that this medical examination is to his advantage. In this education one point should be particularly emphasized: whenever a workman allows the disease to run until he is disabled, it is unlikely that even treatment in a sanitarium will render him again able to practice his trade.

In order to prevent tuberculosis it is necessary to have hygienic working conditions, factories with sunlight, fresh air, and cleanliness. The work place must be free from excessive or harmful dust; dry sweeping should never be allowed. Sanitary drinking fountains and washing facilities should be provided. The worker should not be crowded and the working facilities should be such that his body is not held in a cramped or unnatural position. The common rules of hygiene should be enforced in the factory; spitting upon the ground or floor about the plant should be forbidden. Suitable sanitary cuspidors may be provided, if necessary. The workman is often unhygienic in his habits through ignorance; a consumptive grinder, obeying the regulations, may not expectorate on the floor, but instead into the water pan in which his

wheel is immersed. He may thereby spread the bacilli in a spray throughout the air.

Present conditions point to the eventual eradication of tuberculosis from the human race. As this elimination progresses it brings a tremendous economic gain. Tuberculosis is a disease of urban and industrial life. The battle against the disease is in large part waged in the workshop.

CHAPTER X

THE LUNGS AND THEIR ACUTE DISEASES
ALSO
HARMFUL GASES

Inflammation of the Respiratory Tract.

There are two types of inflammation of the respiratory tract: one is caused by bacteria and is an infection; the other is caused by the irritation of physical agents such as irritant gases, or dust. The latter is usually followed by bacterial infection; irritation of the respiratory tract is, therefore, a predisposing factor to infection. Such infectious diseases as coryza, bronchitis, and pneumonia may affect persons without regard to their occupations, but persons whose occupations involve continual irritation of the respiratory tract are especially liable to infection.

The upper portions of the respiratory tract, the nose, throat, and trachea, are subject to irritation and inflammation more often than the lower, the bronchi and lungs. The deeper the inflammation, the more serious are its consequences; coryza alone is never fatal, while pneumonia frequently is. Inflammation of the deeper respiratory structures usually results from a downward extension of a comparatively harmless inflammation in the upper structures.

All of the respiratory passages except the deepest structures of the lungs are covered with mucous membrane. An inflammation of mucous membrane is of the catarrhal type. The mucous membrane becomes swollen and there is a profuse flow of mucus. Catarrh is commonly regarded as a chronic condition, but this is not necessarily the case, for any inflammation of the mucous membrane associated with an increased flow of mucus is correctly called catarrh. The condition may become chronic if the infection or irritation persists. Chronic catarrh readily becomes aggravated into an acute inflammation.

Coryza or Acute Catarrhal Fever.

Coryza, or cold in the head, is an infectious disease. It prevails most extensively during the changeable weather of late autumn and of spring. Coryza may occur in the form of epidemics; more often the outbreak is local, occurring among the members of a household, school, or workshop. Although any person, however healthy, may contract a cold if exposed, there are predisposing factors which greatly increase susceptibility. These factors are dry heated air, dust, drafts, sudden changes of temperature, exposure to cold and wet, improper food, and other conditions which lower the vitality or irritate the respiratory tract. Even with these predisposing factors, a cold cannot develop unless there is exposure to infection from another person who has a cold, or unless the infection already exists in the individual as a mild chronic state. Arctic explorers, in spite of exposure to severe weather conditions, do not contract colds until they return to civilization; usually they are then immediately reinfected and experience a severe cold.

Most of the symptoms of coryza are local, although in severe cases there may be fever and pains in the back and limbs. The mucous membrane of the nose is swollen and secretes copiously. The conjunctiva of the eyes is reddened and the mucous membrane of the tear duct is also swollen so that the eyes "run." The sense of smell is temporarily lost, and most of that of taste, through the occlusion of the nose. If the inflammation closes the eustachian tube hearing is impaired; if the infection spreads to the middle ear earache may result.

Coryza is largely self-limited; that is, it runs a regular course, gradually decreases in intensity, and terminates in one or two weeks. Treatment has little effect in shortening the attack, although it may relieve some of the unpleasant symptoms.

Coryza is never itself fatal, although it may lead to serious and even fatal complications. The disease may extend into the nasal sinuses and cause sinusitis. It may also extend downward and cause pneumonia. The subject's vitality is depressed, and this condition favors the development of other infections and hastens the progress of chronic diseases such as tuberculosis. The com-

mon cold is usually regarded as trivial, but the sum total of inconvenience, suffering, and economic loss which it entails entitles it to be considered in the aggregate as one of the most serious diseases.

The infection of coryza is conveyed in the secretions from the nose and mouth and is transmitted by "contact." Droplets may be sprayed to other persons in talking, sneezing, or coughing, or the secretion may contaminate food or articles of common use, such as towels, dishes, and glasses, or pass from hand to hand.

Influenza.

Influenza, or la grippe, is a pandemic disease appearing at irregular intervals. Following the pandemics there are repeated outbreaks of the disease in decreasing intensity for several years. These great pandemics have been recognized since the sixteenth century. There were four during the last century—1830-3, 1836-7, 1847-8, and 1889-90, and in the present century one, 1918-19. Most of these pandemics have begun in the Far East and within a year have spread to every part of the world reached by commerce. The duration of the epidemic in any one locality is from six to eight weeks.

Influenza attacks without discrimination; as a rule about 40 per cent of the population develop the disease. Fortunately, the death rate is usually low, averaging approximately 0.5 per cent. It is, however, a very serious and often fatal disease when acquired by old persons or those with tuberculosis. It must be kept in mind that in a nation of 150 million the morbidity of 40 per cent is 60 million people ill within a month or six weeks and 0.5 per cent mortality comes to 300,000 dead in the same time.

Influenza of the respiratory tract is the most common form of the disease. It may, however, attack other organs of the body so that the disease shows a variety of forms. Thus there may be influenza of the nervous system with inflammation of the brain and occasionally paralysis, or influenza of the digestive system with jaundice, nausea, and vomiting. The usual respiratory form of the disease starts with a coryza; there is a high temperature and usually extreme debility. In severe cases the

disease extends into the deeper respiratory structures and causes bronchitis and pneumonia; the great majority of the deaths from influenza result from this pneumonia. A severe attack of influenza leaves the mind in a depressed condition. The general health may also be impaired for many months.

The disease is spread by contact in the same manner as that discussed under tuberculosis. The secretions from the nose and throat carry the infectious agent. Symptoms appear within three or four days after exposure. No regular immunity is conferred by one attack of the disease; the same person may have it several times. Some persons, however, are apparently not susceptible.

Influenza is spread by the close association of persons, particularly indoors. In theaters, churches, stores, and railway cars the conditions are conducive to the wide and rapid transmission of the disease. During some pandemics the inmates of certain prisons, by reason of their isolation, have remained entirely free from the disease. Although such isolation is not practicable for the public at large, even for the relatively short time during which the disease persists in any locality, nevertheless the spread of the disease is impeded by discontinuing all public gatherings such as in theaters and churches.

During an influenza epidemic all persons in stores and factories, and elsewhere when practicable, having a coryza, should at once be sent to their homes. (For school children this should apply to colds at all times.) Gauze respirators worn over the nose and mouth hinder the spread of the disease by preventing both the scattering of the infectious material in droplets by persons who have the disease and by preventing the inhalation of these droplets by others. During the last pandemic some cities passed ordinances requiring all persons to wear respirators when in public buildings. Especial care should be taken to sterilize with boiling water all dishes and drinking glasses used in restaurants or soda fountains.

Bronchitis and Bronchopneumonia.

Bronchitis is an inflammation of the mucous membrane of the bronchial tubes. It is a common sequel to coryza and influenza, and results from a downward extension of the infection. It

often follows measles and whooping cough in children. Although the disease is rarely serious in strong adults, it is often fatal, through the consequent pneumonia, in young children and in old persons. The fatalities result from the further extension of the inflammation into the finer bronchi, atria and alveoli of the lungs, with the development of bronchopneumonia.

Those who work largely indoors and at sedentary occupations are more liable to bronchitis than are persons who live an outdoor life. Dust, dry heated air, and irritant gases or vapors are conducive to the development of bronchitis. Furthermore, the same predisposing factors increase the likelihood of the disease extending into bronchopneumonia.

In mild cases of bronchitis there is little fever, but in severe cases the temperature may range from 100° to 102°. There is a racking cough with severe pain in the chest, particularly beneath the breastbone. In favorable cases the cough "loosens" after a week or ten days and recovery follows. If instead of recovery the bronchitis progresses to bronchopneumonia the symptoms become more severe. The temperature may rise to 104° and shortness of breath becomes marked. When recovery occurs it is gradual and not by crisis, as is the case with lobar pneumonia.

Unlike lobar pneumonia, which is caused by infection with the pneumococcus, bronchopneumonia is caused by almost any type of bacteria which may infect the respiratory passages. Bronchopneumonia is not strictly, in adults, an infectious disease, for the organisms necessary for its development exist in any catarrhal state of the upper respiratory passages. The disease may attack very young children without any of the usual predisposing factors, but is more often a sequel to some other disease such as measles.

The following table shows the relative number of deaths from bronchopneumonia in some trades. It is here seen that, as in tuberculosis, the rate is high in the trades associated with dust, but that, unlike tuberculosis, dust of any irritating character, and not silica alone, is a predisposing factor. Furthermore, the high rate among chemical workers is indicative of the part played by irritant fumes in causing the disease. The low rate among persons engaged in outdoor occupations is noteworthy.

TABLE VI

MORTALITY FROM BRONCHOPNEUMONIA IN VARIOUS TRADES (ENGLAND AND WALES, 1900–02)

Occupation	Mortality per million
Farmers	1,400
Railway engine drivers	2,600
Fishermen	2,700
All males	5,700
Coal miners	7,900
Wood turners	9,000
Cotton workers	9,200
Chemical workers	12,000
Brush-makers	13,000
Cutlers	13,200
Glass-makers	13,200
Earthenware-makers	25,300

Lobar Pneumonia.

Lobar pneumonia is an infectious disease caused by a specific organism, the pneumococcus. It is one of the most prevalent and fatal of acute diseases. The onset of the disease is sudden and is usually accompanied by a severe chill. The temperature rises to from 103° to 105° and the breathing is very rapid. Usually there is severe pain in the side of the chest. Profound prostration results from the absorption of toxic products from the bacteria in the lung tissue.

Pneumonia is a self-limiting disease. In nonfatal cases it terminates abruptly by what is known as crisis. This crisis usually comes on the fifth to ninth day of the disease. Although the serious symptoms disappear, the patient is left weak, the convalescence is long, and full strength is not recovered for many months. The pneumococci frequently find their way into the blood and may cause infections of parts of the body other than the lungs, thus complicating the disease.

There are four or more types of the pneumococcus; but they can be differentiated only by delicate serological tests. The different types are designated by numbers. Types 1, 2, and 3 are

responsible for 80 per cent of the cases of pneumonia and are found only in the mouth and throat of persons recovering from the disease or those in direct contact with such cases. Immunizing sera have been prepared for groups 1 and 2, and are of assistance in treating the disease when it is caused by these particular organisms. The pneumococcus of group 4 is sometimes found in the mouths of healthy people, but since it is responsible for only 20 per cent or less of all cases of pneumonia, it appears that the disease is usually transmitted from those who have the disease. The infection is spread by "contact."

There is no complete immunity to lobar pneumonia; one attack predisposes rather than protects against a second. Nevertheless, there is at least a partial immunity, for all persons do not acquire the disease, although the exposure must be quite general. Robust persons in the best of health are sometimes stricken with lobar pneumonia; but usually there is some predisposing debility, for the degree of immunity to the disease appears to depend largely upon good health and hygienic living. Any factor which lowers vitality increases susceptibility to the disease.

The excessive use of alcohol predisposes to the development of pneumonia; men in trades prone to alcoholism, such as innkeepers, coal heavers, cab drivers, stevedores, and general laborers, and also club men who are habitual drinkers, show a high death rate from pneumonia. The common belief that alcohol will ward off the effects of exposure to cold or wet is a dangerous fallacy. Its action under these circumstances is harmful. Alcohol dilates the blood vessels in the skin and causes a greater flow of blood to the surface, thus increasing the loss of heat from the body. Alcohol, while giving the sensation of warmth, actually lowers the temperature of the body. The chill from exposure can best be overcome by hot drinks. A pint of coffee drunk at 115° F. will yield 15 B. T. U. (approximately 4 kilocalories) of sensible heat, thus doubling the heat production of the body for a period of about three minutes.

Congestion of population increases the incidence of pneumonia. Thus General Gorgas, in the Isthmus of Panama, by removing the laborers from large overcrowded barracks into single huts and rooms with not less than 50 square feet of floor space per person,

reduced the pneumonia rate in one year from 18,400 to 2,000 per million. Exposure to hardship and cold are predisposing factors for pneumonia and so is dry heated indoor air. Exposure to heat such as occurs in the steel and glass industries, with subsequent chilling during the winter months, predisposes to pneumonia. From a like reason the employees in cotton mills, where the air is hot and humid, show a greater incidence of pneumonia than the workers in other textile industries. Chronic catarrhal conditions in the respiratory passages increase the susceptibility to pneumonia; accordingly, in trades in which the workers are exposed to dust or irritant fumes there is not only a greater incidence of bronchitis and bronchopneumonia, but also of lobar pneumonia.

Noxious Gases and Vapors.

In modern industry, and even in everyday life, noxious gases and vapors are liberated into the air in increasing quantities. The inhalation of such volatile poisons to a greater or less extent is today almost universal. Fortunately, not all of these substances are extremely poisonous, but comparatively few are entirely free from ill effect. The inhalation of many of these substances in sufficient quantity is deleterious to health and may even cause death. The nature of the consequences depends upon the kind of gas or vapor, and upon the length of time and the concentration in which it is breathed. Noxious gases (including vapors) may be classified according to their action on the body into four main groups: irritants, asphyxiants, volatile drugs and volatile inorganic poisons.

Irritant Gases.

An irritant gas is one which induces inflammation in tissues with which it comes in contact. The conjunctiva of the eye and the surfaces of the respiratory tract are moist and delicate. The action of irritants is more severe upon these tissues than upon the skin. The destruction or corrosion of the tissues by the irritants in the concentrations ordinarily inhaled is very slight and is not the direct cause of the ill effects which follow poisoning with these gases. They arise from the inflammation

which follows the initial insult to the tissue. A similar reaction may be seen on the skin in sunburn. The actinic light of the sun is not sufficiently intense to cause visible destruction of the skin, or any immediate effect like burning with a flame or hot iron, but inflammation develops later and what we term "sunburn" is due to this inflammation.

The action of all the irritant gases is essentially the same; nevertheless, the symptoms which follow their inhalation are different. Thus ammonia gas causes immediate coughing, sneezing, and severe inflammation of the throat and larynx, while phosgene does not give rise to any marked symptoms at the time of inhalation, but death may follow some hours later from the inflammation induced in the lungs.

The differences in the symptoms caused by the various irritants result from the different localities which they attack in the respiratory tract. The point of action of an irritant is determined by its physical and chemical character, particularly its solubility. Thus a gas which is very soluble in water is taken out of the inspired air by contact with the first moist tissue which it reaches. Less soluble irritants spread their action more extensively along the respiratory tract. Slightly soluble irritants, or those which liberate their irritant principle only on hydrolytic decomposition, affect the upper respiratory tract only slightly, for little of the substance is absorbed there. The main damage is done deep in the lungs. The deeper in the respiratory tract the irritant acts the more serious are the consequences.

Acid fumes and ammonia are typical of very soluble irritant gases. Their inhalation causes immediate coughing and sneezing and inflammation of the throat and larynx. In fatal poisoning by this type of irritant death results from the swelling of the larynx shutting off the trachea.

Chlorine and sulphur dioxide are typical of moderately soluble irritant gases. Their inhalation is almost immediately followed by coughing and sneezing. The inflammation which they cause is particularly severe in the trachea and bronchial tubes. This inflammation is often followed by infection with bacteria from the mouth and throat; bronchitis and pneumonia follow.

Nitrogen peroxide and phosgene are typical irritant gases of

low solubility. They act largely upon the lungs and cause death from edema of the lungs. Fluid from the blood seeps through the walls of the alveoli and clots in the air spaces, thus preventing the blood from being aërated. When lung edema occurs it develops from twelve to twenty-four hours after exposure to the irritant and is usually fatal. Nitrogen peroxide arises as reddish brown fumes from the action of nitric acid upon organic material. Phosgene has been used as a war gas; it also arises from the action of carbon tetrachloride upon heated surfaces. Carbon tetrachloride is sold as a fire-extinguishing fluid under the trade name of Pyrene and for "dry cleaning" under the name Carbona. The evolution of phosgene from these substances on a fire or any heated surface renders their use unsafe in confined quarters.

Infection after Exposure to Irritant Gases.

Men poisoned by irritant gases usually either die within a few days or appear to recover completely. Chronic inflammations or scarring may, however, result in the bronchi or lung tissue with areas of persisting infection and abscesses. The general health may thus be impaired for a long time. Persons thus afflicted frequently appear normal when at rest, even under medical examination, but they are incapable of anything more than the most moderate exertion.

Inflammation of the lungs caused by irritant gases does not lead directly to tuberculosis, as is the case with irritation from silica dust. The statistics of the subsequent health of soldiers gassed during the war indicate that, when the lungs have once healed, they are not appreciably more liable to tuberculosis, than would otherwise have been the case. On the other hand, when the subject has suffered a period of decreased vitality or ill health as a consequence of the action of an irritant gas, then tuberculosis may develop as it might during decreased vitality from any other cause.

Prolonged exposure to sublethal concentrations of irritants may induce chronic poisoning; the chief effect is a moderate inflammation of the respiratory tract and the chief symptom a sharp cough. If the exposure is a more or less regular part of the man's working conditions, the inflammation passes into a chronic

catarrhal state. The cough then becomes a less marked feature and the worker appears to have acquired a partial tolerance to the gas. No true tolerance exists, however; the cough is less active merely because of the protection afforded the mucous membrane of the upper portion of the respiratory tract by the tenacious mucus with which it is coated. This protection does not extend to the tissues of the deeper bronchi or lungs; it rather exposes them the more because the worker can now tolerate the irritant gas with less immediate discomfort and for a longer time.

Asphyxiant Gases.

An asphyxiant gas or vapor is one which induces suffocation by some means other than prevention of breathing. Gases which are inert physiologically, such as hydrogen, nitrogen, and methane, act as asphyxiants by diluting the oxygen of the air, so that it becomes insufficient for the needs of the body. Carbon monoxide and the gases and vapors of the cyanide compounds induce asphyxia through their effects after absorption. Carbon monoxide itself combines with the hemoglobin of the blood so that it cannot carry sufficient oxygen for the needs of the body. Cyanides affect chiefly the tissues themselves, so that they are unable to use the oxygen which is brought to them.

Symptoms of Asphyxia.

The nervous system is more sensitive to deprivation of oxygen than is any other tissue. Asphyxia of mild degree or short duration abolishes the function of the nervous system and leads to unconsciousness; severe asphyxia maintained even for a short time may injure the nervous system irremediably. The symptoms arising from asphyxia depend upon the degree and duration of the oxygen deprivation suffered by the nervous system. In severe asphyxia such as that induced by inhalation of pure nitrogen, or even a low concentration of hydrocyanic-acid gas, unconsciousness develops at once, the man falls to the ground as though struck by a blow on the head; if the asphyxia continues, he dies within a few minutes. In less severe asphyxia the symptoms develop more slowly; in many respects they resemble those of alcoholic intoxication. The ability to maintain attention is dimin-

ished, as is also the coördination for such finer skilled movements as writing. Next the judgment and emotions, particularly the temper, become affected. Muscular effort performed at this stage leads to rapid fatigue and exhaustion. Asphyxia of greater degree is followed by inability to perform such muscular movement as walking. Asphyxia is not painful (although the recovery is). The first effect noticed by the man undergoing the asphyxia may be his inability to move. Unconsciousness soon follows. Breathing stops, but the heart continues to beat for six or eight minutes longer. Death follows.

If the asphyxiation has not been prolonged and is relieved at any stage short of failure of breathing, the symptoms usually pass off quickly and aside from headache and nausea the effects are not often serious. If breathing has stopped it does not as a rule become reëstablished unless artificial respiration is performed.

Nitrogen is the principal constituent of the "black damp" and methane of the "fire damp" encountered in mines. A man can breathe air containing 30 per cent or even more of nitrogen or methane without discomfort; the oxygen of the air is thus reduced from the normal 21 per cent to 14.7 per cent. An atmosphere which will support the combustion of a candle contains sufficient oxygen to support life (see Chapter VIII). In making the flame test the danger is that the methane which is abundant in some coal mines will be ignited; the "safety lamp" of miners is shielded with wire gauze to prevent such explosions. It also enables the miner to estimate the amount of methane from the appearance of the cap (the burning methane above the flame) of his lamp.

Asphyxiation resulting from incarceration in an air-tight inclosure such as the vault of a bank is rare, but the length of time that a man can exist under such circumstances is of interest. It can be readily calculated. A preliminary point to be considered is the fact that few structures, other than metal vaults, are air-tight; the plastered walls of the ordinary room, or even thick concrete walls, admit air with sufficient freedom to keep the oxygen of the room from being appreciably diminished, even when occupied by many people; carbon dioxide is even more diffusible. The length of time a man can remain in an air-tight inclosure without

suffering seriously from asphyxia depends upon the volume of oxygen consumed and the volume of air present. At rest the average man consumes 200 to 300 cubic centimeters of oxygen per minute. A period of seven hours would thus be required to reduce the oxygen in one cubic meter of air to one half its normal content, an amount still sufficient to support life.

Carbon Monoxide.

Carbon monoxide is the most common of the noxious gases; more deaths result from inhalation of carbon monoxide than from all of the other noxious gases combined.

Carbon monoxide is colorless, nearly odorless, and when ignited burns with a blue flame. It is produced by the incomplete combustion of carbonaceous material, and by the partial deoxygenation of carbon dioxide when the latter is passed over red-hot coals.

Illuminating gas is a common agent in carbon-monoxide poisoning. Two types of this gas are manufactured: coal gas and water gas. The former is made by the destructive distillation of coal; it contains from 4 to 8 per cent of carbon monoxide. Water gas is made by passing steam over red-hot coke; it contains about 40 per cent of carbon monoxide. Most cities in America are supplied with illuminating gas containing both coal gas and water gas. The percentage of carbon monoxide ranges between 10 and 30 per cent.

The Borough of Manhattan in New York City has annually some 400 deaths from illuminating gas; about 50 per cent of these are suicides, the others are caused by leakage of the gas. One of the common causes of accidents is the rubber hose connection used to attach portable gas stoves and lamps to the gas cock. Rubber hose deteriorates with age and leaks, and the ends are often accidentally pulled from the stove or cock. The company which sells the illuminating gas has no control over the use of hose connections by the consumer; the jurisdiction of the company ceases at the meter, at which point the gas becomes the property of the consumer. Some states have wisely prohibited the use of hose for making gas connections.

The gas generated in blast furnaces contains approximately 25

per cent of carbon monoxide. Gas poisoning about blast furnaces is especially dangerous, for the partially asphyxiated man is there liable to accidents such as falls or burns. The principal poisonous element in coal smoke is carbon monoxide. Whole households have been poisoned by a leak of smoke through a crack in the dome of a hot-air furnace. When firemen are overcome by smoke it is usually carbon-monoxide poisoning from which they are suffering.

The exhaust gas from internal-combustion engines contains carbon monoxide. The percentage of this constituent in the exhaust varies with the completeness of combustion, and this in turn depends upon the proportions of gasoline and air in the mixture drawn into the cylinders. The "richer" the mixture the higher is the percentage of carbon monoxide formed. From the excessively rich mixture made by "choking" the carburetor inlet when starting the cold engine, 10 per cent or even more carbon monoxide may appear in the exhaust. When the carburetor is adjusted to give the leanest mixture upon which the engine will run at all, the exhaust contains only a fraction of 1 per cent of carbon monoxide. Starting with the rich mixture from the choked carburetor, the power developed by the engine increases as the mixture is made leaner. The maximum of power is reached, however, before the mixture is thinned to the point of lowest carbon-monoxide production. The carburetor adjustment on most automobiles is set for a maximum power and smoothness of operation; it furnishes a mixture which produces a large amount of carbon monoxide, ranging usually from 5 to 7 per cent. The amount of carbon monoxide produced varies with the size of the engine and the speed at which it is run. The average passenger car or truck produces about one cubic foot of carbon monoxide per minute for each twenty horse power.

When automobiles are operated out-of-doors the exhaust gas does not usually constitute a serious health hazard. In the traffic congestion in large cities, however, the street air may be contaminated with more than .01 per cent of carbon monoxide, which is considered the maximum for prolonged exposure. Headache and irritability of temper may result in those who are exposed for long periods to the contaminated air. Those in the street

are not the only persons exposed to this air, for in the winter time at least, much of the air with which tall buildings are ventilated enters at the street level. Thus the gas may be spread by stairways and elevator shafts to all parts of the building, even to the highest stories.

The replacement of the common horizontal exhaust pipe with one extending vertically and opening above the top of the car has been suggested as a means of lessening the contamination of the air in city streets. The hot gases coming from the exhaust tend to rise; if they start near the ground, as is the case with the horizontal exhaust pipe, all of the air above this level is contaminated, but if the exit is above the top of the car and thus over the heads of the occupants and pedestrians, they are left in an area of air which is relatively little contaminated. The use of vertical exhaust is even more important when the engines of cars are run indoors than upon the street. An automobile, or other internal-combustion engine, operated indoors constitutes a serious health hazard unless contamination of the air is prevented. Many deaths result in the winter months in private garages from running the motor of the car with the garage doors closed. These buildings are usually small and the concentration of carbon monoxide rises almost immediately to a dangerous level. Running the average motor car for five minutes in a garage with dimensions of 12 x 12 x 10 feet will result in a concentration of some 0.3 per cent of carbon monoxide; if the engine is cold and the mixture enriched to assist starting a concentration as high as 1 per cent of carbon monoxide may develop. These concentrations rapidly cause disablement, unconsciousness, and death. The effects come on suddenly and without warning. The legs are paralyzed first, the person exposed to the gas falls, and is unable to rise or even crawl.

In large public garages, motor-repair shops, testing rooms, freight warehouses, mines, subways, or any other inclosed space where automobiles are operated, serious results may follow from the contamination of the air with exhaust gas. The concentration of carbon monoxide does not rise as rapidly nor as high as in a small garage, but the exposure is longer and the men who work in the contaminated air suffer in health. They have head-

ache, their temper is irritable, their judgment is affected, and their efficiency is reduced. General ventilation usually fails to reduce the carbon monoxide to a harmless concentration and is effective only under special and suitable circumstances as in the vehicular tunnels under the Hudson River; but the volume of air used there is so large that it would involve a prohibitive expense for ventilating a garage even if unheated. In the case of the passengers using the tunnels the exposure is limited to a short time; a quarter or at most half an hour.

Automobile exhaust may prove a source of danger even out-of-doors when the person operating, loading, or unloading a truck stands in the rear of the car while the engine is allowed to idle. The air in line with and within a few feet of the gas pipe contains a high concentration of carbon monoxide. Repeated exposure may result in the absorption of a sufficient amount of the gas to cause some degree of poisoning. Carbon monoxide affects the judgment like alcohol. The person intoxicated by either is unaware of his faulty judgment, but his liability to accidents is greatly increased.

Action of Carbon Monoxide.

Carbon monoxide is poisonous because it combines with the hemoglobin of the blood and prevents this substance from transporting oxygen to the tissues. Aside from this one reaction in the body carbon monoxide is an inert gas. It is neither burned nor otherwise destroyed in the body; and when pure air is again breathed the gas that has been previously absorbed is gradually eliminated. Carbon monoxide itself does not harm the tissues of the body; the poisonous effects which follow the inhalation are the secondary results of the asphyxia occurring during the time the hemoglobin is combined with carbon monoxide.

Both oxygen and carbon monoxide combine with hemoglobin; therefore when hemoglobin is exposed to the two gases, as when air contaminated with the gas is breathed, each gas combines with the hemoglobin in a proportion determined by two factors: (1) the amount of each gas present; and (2) the relative attraction which each exerts toward hemoglobin. The reaction of hemo-

globin in the presence of carbon monoxide and oxygen is expressed by the equation:

$$\underset{\text{(oxyhemoglobin)}}{HbO_2 + CO} \rightleftarrows \underset{\text{(carbon monoxide hemoglobin)}}{HbCO + O_2}$$

The attraction between carbon monoxide and hemoglobin is 300 times as great as that between oxygen and hemoglobin. Therefore when the air to which blood is exposed contains 1/300 as much carbon monoxide as oxygen, one-half of the hemoglobin combines with the carbon monoxide and half with oxygen. Hemoglobin in combination with carbon monoxide is useless in the body; the blood is deprived proportionately of its ability to carry oxygen. Pure air contains 21 per cent of oxygen: therefore when air containing 0.07 per cent (1/300 x 21) of carbon monoxide is inhaled the gas will combine with and render useless one-half of the hemoglobin in the blood. The displacement of half the oxygen in the blood by carbon monoxide results in a degree of asphyxia verging on unconsciousness.

Although the inhalation of 0.07 per cent of carbon monoxide will displace one-half of the oxygen from the blood, the inhalation must be continued many hours before this end is reached. This time would be required for a sufficient volume of air and carbon monoxide to be breathed. The body of a man of average size contains about five liters of blood and the hemoglobin of this amount of blood has a capacity of approximately one liter of oxygen (20 volumes per cent). The blood would combine with the same volume of carbon monoxide. About half a liter of the gas must be absorbed in order to produce a 50-per-cent saturation of the hemoglobin with carbon monoxide. With a volume of breathing of eight liters per minute and with 0.07 per cent of carbon monoxide in the air, only 0.0056 of a liter of carbon monoxide are inhaled each minute. Of this only about two-thirds reach the lungs, so that only 0.0036 of a liter are absorbed into the blood. If the rate of absorption were uniform, three hours would be required for 50 per cent of the hemoglobin to be combined with carbon monoxide. In reality, however, the rate of absorption decreases as the per cent of carbon monoxide hemoglobin in the blood increases, so that ten or twelve hours of ex-

posure are required to effect a 50-per-cent combination. The rate of absorption is proportionately greater with higher concentrations of carbon monoxide in the air, and also with the greater volume of breathing resulting from exercise.

The size of the individual also has an influence upon the time required for a certain percentage of the blood to combine with carbon monoxide. The volume of blood in the body varies with the weight; the metabolism, and hence the volume of air breathed, vary with the surface area of the body. The smaller the animal the greater is the surface in relation to the weight, and so to the volume of blood; the rate of saturation of the blood with carbon monoxide varies inversely with size. Babies succumb to carbon monoxide more quickly than adults; while a very small animal, such as a mouse or canary bird, is overcome in about one-twentieth the time required for a man. Mice and canary birds are frequently used to indicate the presence of dangerous amounts of carbon monoxide in the air of mines. After the animal has collapsed there is still time enough for the men of a rescue crew to escape.

The harmful effects of carbon monoxide depend upon the proportion of oxygen displaced from the blood and the length of time this oxygen deficiency persists. The combination of 15 per cent or less of hemoglobin with carbon monoxide does not give rise to any noticeable symptoms. As the combination of 15 per cent of the hemoglobin with carbon monoxide is equivalent to equilibrium with 0.01 per cent of carbon monoxide in air, this concentration is the highest properly allowable for any long exposure. The air in the streets of some of our cities, as, for instance, Fifth Avenue, New York, shows at times a concentration higher than this from the exhaust of automobiles. Concentrations higher than 0.01 per cent can be tolerated if the period of exposure is shortened, so that no more than 15 per cent of the hemoglobin enters into combination with the carbon monoxide. Thus, for the vehicular tunnel under the Hudson River a maximum of 0.04 per cent has been adopted as the standard for an exposure not to exceed one hour.

Severe headache and some emotional disturbance may result when 15 to 30 per cent of the hemoglobin is in combination with

carbon monoxide. These symptoms are exaggerated by any exertion. More oxygen is used by the body during exercise and the impairment in its transportation is felt more acutely. Thirty to fifty per cent saturation of the blood with carbon monoxide may cause very severe headache, shortness of breath, and nausea; if exercise is attempted, fainting may result. Sixty-per-cent saturation brings unconsciousness, and any higher saturation may result in death.

As low as 0.1 per cent of carbon monoxide in air will cause unconsciousness and death if the exposure is prolonged; 1.0 per cent will kill in a very few minutes. The following table summarizes the effects of exposure to various concentrations of carbon monoxide in relation to the time of exposure. The concentrations given are parts of carbon monoxide in ten thousand of air and the time in hours:

(1) — Time × concentration = 3, no perceptible effect.
(2) — Time × concentration = 6, a just perceptible effect.
(3) — Time × concentration = 9, headache and nausea.
(4) — Time × concentration = 15, dangerous.
(5) — Time × concentration = 25, deadly.

Thus 0.1 per cent or 10 parts of carbon monoxide in 10,000 of air gives no perceptible effect for an exposure of twenty minutes ($1/3 \times 10 = 3$), but would be dangerous for an exposure of 1½ hours, ($3/2 \times 10 = 15$).

On returning to fresh air after exposure to carbon monoxide, the gas which has been absorbed is eliminated at a rate which depends largely upon the volume of air breathed. During the period of elimination the asphyxia continues in a degree depending upon the carbon monoxide still in the blood. Rapid elimination of the gas is therefore extremely desirable, for it lessens the harmful effects of the asphyxia by shortening its duration. The inhalation of dilute carbon dioxide (to be discussed under resuscitation from asphyxia) is now widely used to stimulate the breathing and thus to hasten the elimination of carbon monoxide.

Cyanide Compounds.

The cyanides when brought in contact with living matter arrest oxidation by acting upon the catalysts through which the

oxidations are carried out. Asphyxia thus results because oxygen cannot be utilized. Poisoning by the inhalation of cyanide vapor is rare except from hydro-cyanic-acid gas, which is used for killing rats on ships to prevent introduction of bubonic plague. The symptoms which arise from its inhalation resemble those from carbon monoxide, but develop much more rapidly; indeed, the cyanides are among the most rapidly fatal of all poisons. The absorbed cyanide is converted in the body to harmless compounds, and if the amount absorbed has not been too great life can be saved by maintaining artificial respiration.

Volatile Drugs.

The most common of these substances are the volatile hydrocarbons from petroleum and coal tar and the various alcohols, ethers, and esters used in industry. All of these substances act more or less like alcohol in the various stages of drunkenness and in the same manner as the anesthetics used in surgical operation. The hydrocarbons from petroleum cause intoxication similar to that of ethyl alcohol, and unless death occurs in the acute stages of the poisoning there are usually no serious after effects. The hydrocarbons from coal tar not only produce intoxication, but in addition after prolonged exposure they cause destruction of various tissues in the body and other serious after effects. The compounds of methyl, such as methyl alcohol and methyl bromide, although not derived directly from coal tar, exhibit in high degree the destructive action upon certain tissues. Numerous cases of blindness have followed the inhalation of the vapors of wood alcohol from lacquer applied in confined quarters.

Volatile Inorganic Poisons.

Of these inorganic substances the most important are phosphorus, mercury, and hydrogen sulphide. Mercury alone among the metals has a sufficiently high volatility to permit poisoning from its vapors. The fumes arising from other metals in the molten state are dust resulting from the condensation of the vapors evolved only at high temperatures. Metals such as lead when in the form of volatile organic compounds such as lead tetra ethyl may, however, be absorbed through the lungs.

Mercury is volatile even at room temperature. Mercury spilled upon wooden or concrete floors or upon carpets and mixed with dirt breaks into minute globules which expose a large surface for evaporation. Poisoning in this way may result from the spilling of relatively small amounts of the metal. The inhalation of the vapor causes changes in the gums, leading to pyorrhea, intestinal disturbances, and changes in the nervous system involving tremor of the hands and a peculiar type of embarrassment.

The vapor of phosphorus, when inhaled over a long period, causes changes in the bones, so that their resistance to bacteria is reduced. The teeth decay, with the introduction of pus into the jawbone, and this is followed by the destruction of the entire jaw (phossy jaw). The gruesome deformity caused by inhaling phosphorus vapor in the manufacture of matches has led to the abolition of the use of white phosphorus for this purpose.

Hydrogen sulphide is formed by the decomposition of organic material. It occurs in sewer gas, during the manufacture and use of dyes, in purifying coal gas, and during the distillation of petroleum oil containing sulphur. The gas has a smell characteristic of rotten eggs. In very low concentrations hydrogen sulphide irritates the eyes and causes an inflammation resembling pink eye. In higher concentrations it paralyzes respiration. Hydrogen sulphide is nearly as poisonous as cyanide and in high concentrations it is one of the most rapidly fatal of all poisons.

Prevention and Treatment of Poisoning by Noxious Gases.

In order to prevent poisoning by noxious gases three requirements are essential: (1) The conditions under which each gas occurs must be known, and also the physiological effects induced by various concentrations and by various durations of exposure. (2) This knowledge must be applied so as to prevent the dissemination in the respired air of a toxic concentration of the gas. And (3) if the dissemination cannot be avoided, those who are exposed must be equipped with apparatus to protect them against inhalation of the gas.

Lack of Legal Protection Against Noxious Gases.

At the present time there is an almost complete lack of federal or state laws applying specifically to the manufacture, handling,

and sale of substances which are poisonous, other than foods and drugs. This lack of legal protection is the more striking when it is compared with the full and explicit regulations, inspection and analysis, applying to the shipment and sale of food products. The public is thus effectively protected against food poisoning, and indeed even against materials which are only mildly detrimental, if they are to be taken into the body through the alimentary tract. On the other hand, the injury to the public health induced by detrimental materials, even the most poisonous, which enter the body through the respiratory tract, is not generally recognized; and relatively little protection against such hazards is afforded by legislation. For example, the addition of benzoate of soda or artificial coloring matter to a food product must be indicated by a proper label on the container; but the presence of benzol in a quick-drying paint, of carbon disulphide or tetrachlorethane in a solvent, is often disguised under a trade name. Yet benzoate of soda in food can at most only impair health slightly, while benzol in paint causes the death of men who use it in a confined space for a few hours. A dangerous organometallic compound, lead tetraethyl, is now blended with gasoline and is sold throughout this country; it is noteworthy that some other countries are prohibiting the use even of lead paints. The public does not know the dangers of benzol or the insidious nature of lead poisoning. In respect to the volatile poisons, and indeed to all harmful substances in industry and in interstate trade, it is of the highest importance that the same sort of inspection and regulation should apply as in the matter of food products under the pure food law. The federal and state governments should also provide for more extensive scientific investigation and publication for the education of manufacturers and workmen. Public funds expended for this purpose would bring an ample return, for industry would not then be hampered by the illness of workmen or loaded with the cost of their deaths. With knowledge and care even the most poisonous substances can be produced and used safely in industry. The sale of such substances to the general public is, however, fraught with great danger.

New compounds of volatile nature are being introduced into manufacture and trade in increasing number and amount. Phy-

siological investigations to define the dangers attending the use of these substances should be a matter of course prior to their introduction; it should be a legal requirement and strictly enforced. In fact, however, the toxicity of these compounds is generally unknown at the time of their introduction. Physiological information based largely upon experiments on animals would be both less costly and more humane than is the information now gained on men by the statistics of illness, disablement, and death in industry.

Prevention of Atmospheric Contamination.

In order to prevent the dissemination of noxious gases in toxic concentration the physical and chemical characteristics of the substances, and also their physiological action and degree of toxicity, must be known. The mode of preventing a poisonous or unhealthful condition of the air resolves itself then into the engineering problem of controlling the degree of contamination. The requisite standards of ventilation must first be determined experimentally and defined in practical terms, and then arrangements and machinery to effect them must be developed. An example of this type of problem on a large scale occurred in preparation for the construction of the vehicular tunnels under the Hudson River. The first step was to determine the allowable concentration of carbon monoxide from motor exhaust in air to be breathed during the time of passage through the tunnel; the second was the development of a method and means of ventilation to maintain the standard thus defined.

When factories, petroleum refineries, garbage, fertilizer, and similar plants produce harmful fumes or offensive odors, it is generally possible to prevent the escape of these gases and vapors by one or other of two methods. For both methods it is essential to collect in a single large duct the entire effluent air from the chambers where the fumes arise. One of the methods then consists in passing this air through activated charcoal, which readily condenses a wide range of substances. Commercially valuable substances absorbed by charcoal may be recovered by displacement with steam, and the absorptive power of the charcoal is thus regenerated. The other process consists in mixing

a relatively small amount of chlorine gas with the air in the duct. Minute amounts of chlorine in the presence of water vapor destroy many labile substances, including most offensive odors, hydrogen sulphide, etc.

Other Precautionary Measures.

No matter how much care is taken to prevent constant contamination of the air, accidental and temporary contamination must also be anticipated and provision must be made for such accidents. The general type of precaution needed may be exemplified by the following rules applicable to an ammonia refrigerating plant:

(1) The refrigerating equipment, including valves and piping, should be inspected at short and regular intervals, and suitable repairs made immediately when needed.

(2) Every employee should be instructed regarding the dangers from ammonia and trained to avoid them.

(3) No one should be allowed to sleep in rooms adjoining the refrigerating plant.

(4) The room or rooms in which the machinery is installed should have doors opening directly to the outside air. The relation of this room to other parts of the building should be such that escaping fumes cannot invade the other parts or cut off the escape of persons in them. Regulations should be prominently posted and strictly enforced requiring that the exits shall never, even for a few minutes, be obstructed by temporary scaffolding, wheelbarrows or other inpediments to egress.

(5) Gas masks with canisters affording protection against ammonia should be provided; they should be stored in some locality readily accessible to, but outside of, the room in which there is a possibility of the escape of ammonia.

(6) Every workman engaged in repair work on refrigerating apparatus should be required to carry a gas mask strapped to his body or hung around his neck in anticipation of the possible escape of ammonia.

(7) A valve arranged to shut off the ammonia at the storage cylinders should be placed where it can be manipulated from the outside of the building.

Protective Apparatus.

Three types of apparatus are used for protection against the inhalation of noxious gases: (1) gas masks, (2) hose masks, and (3) self-contained breathing apparatus. These three forms of apparatus differ from one another in principle, and each has advantages and disadvantages in relation to the other types. Each is best for its own special use. The greatest care should be taken to avoid inadequate or defective protective apparatus; for it may add death of a rescuer to that of a first victim. As such apparatus, especially the rubber parts, deteriorates rapidly, it must be frequently inspected and regularly renewed.

Unfortunately, there is a widely held belief that a handkerchief, or some other piece of fabric, tied over the mouth and nose constitutes a gas mask. Many lives have been sacrificed to this fallacy. Fabrics that will permit the passage of the respired air will also permit the passage of noxious gases. Moistening the cloth offers protection against only a few substances and for only a short time. The more soluble irritant gases and vapors, when present only in low concentration, may be partially and temporarily absorbed by the moisture; but such makeshift arrangements offer absolutely no protection against the asphyxiants and the volatile druglike substances. Respirators designed to prevent the inhalation of dust afford no protection against noxious gases.

Gas Masks.

A properly constructed gas mask consists of a facepiece of rubber or rubberized fabric, which fits tightly across the forehead, along the cheeks and under the chin, and which is connected by a short piece of flexible and noncollapsible tube to a sheet-metal canister containing absorbent materials. The facepiece is fitted with windows of nonsplintering glass placed in front of the eyes. The canister is worn suspended from the shoulders or strapped across the chest. At the bottom of the canister is a light disk check valve which opens only to admit air, so that the breath is drawn in through the canister. A second valve opens from the facepiece to the outside air; through this valve the breath is exhaled. The canister is filled with layers of various materials, which remove, either by absorption or by chemical reaction, cer-

tain gases and vapors from the air. When the mask is fitted to the face all of the air inspired is filtered through these materials, and is thus purified.

The gas mask in its present form is the highly developed and extremely efficient product of very extensive and careful investigation. It is light, quickly applied, allows freedom of movement,

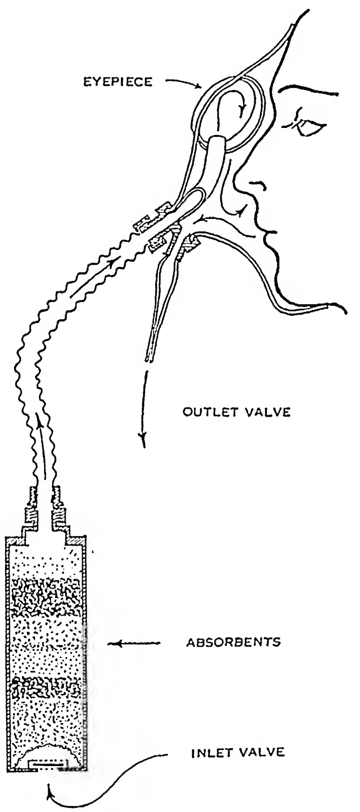


Figure 26. Schema of Gas Mask.

and is purchasable at a reasonable price. It affords effective protection against such gases and vapors as the materials in the canister are designed to absorb. Most canisters are charged with materials intended to absorb only a limited number of closely related gases. The contaminant in the air must be known and the proper canister employed to absorb that type of gas. A canister charged to afford protection only against ammonia, for example,

is useless for such gases as carbon monoxide, or hydrochloric acid fumes; for each of those gases there is a special type of absorbent. There is one type of canister, however, the so-called "all service canister," which gives protection against all gases and vapors found in industry, excepting, of course, high concentrations of the simple asphyxiants. This type of canister is useful when the contaminant in the air is unknown, as is the case when firemen enter chemical storage depots; but has the disadvantage of a relatively short life, owing to the comparatively small supply of each absorbent in the canister, when used against any one particular gas. In most industrial plants the gases which may occur are known beforehand, and the proper canisters should be provided. Canisters filled with only one type of absorbent material afford protection for a longer time than is possible with the all-service canister.

A stripe painted on the canister indicates that it is fitted with filter pads and will protect against smoke, dust, and mists. A gas mask cannot be safely used in an atmosphere seriously deficient in oxygen. The practical limit beyond which a mask should not be used is indicated by the extinction of the flame of a candle or safety lamp. This occurs at about 17 per cent of oxygen in the air; a man is not in serious danger until the oxygen falls below 14 per cent. When, owing to an excess of the simple asphyxiant gases, the oxygen falls below this limit a gas mask ceases to afford protection, even though the absorbent in the canister removes any actively toxic gas. Under such circumstances a hose mask or self-contained breathing apparatus must be used.

Hose Masks.

The facepiece of a hose mask is essentially the same as that of a gas mask; but instead of the inspired air entering through a canister it is brought in through a length of hose, the outer end of which is supplied with fresh air. If the hose is not over twenty-five feet in length and the mask is tight, the force of inspiration will, without serious difficulty, draw air in against the resistance imposed by the hose. If the hose is over twenty-five feet in length, or if the worker must wear the mask for a considerable

time, air should be blown in with a pump. In an emergency a bellows or even a jet of compressed air may be used. The latter is not to be recommended, however, for the air may contain oil. If a jet of compressed air is used the hose should be left open at the end, and the jet should be shot in on the principle of an injector. Whenever possible the air blower for a hose mask should be of the centrifugal type, so that in case it is run at too low a speed or stops entirely the air supply will not be cut off; for enough air may be drawn through a centrifugal pump and even a long hose to permit the wearer of the mask to escape from an irrespirable atmosphere.

The hose mask is especially desirable for work in atmospheres contaminated with the vapors of the lighter petroleum distillates.

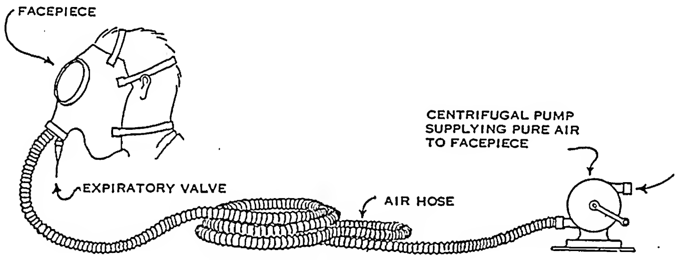


Figure 27. Hose Mask.

In such vapors the life of the canister of a gas mask is of uncertain duration and poisoning may be rapid when the canister becomes exhausted. A self-contained breathing apparatus may also fail, for the vapors may penetrate the rubber fabric and accumulate in the circulated oxygen. A hose mask can be worn in any atmosphere regardless of oxygen content. Its only disadvantage lies in the fact that the wearer's activities are limited by the length of the hose.

Self-contained Breathing Apparatus.

A self-contained breathing apparatus is a portable device for supplying an atmosphere of oxygen which the wearer continually rebreathes, while the carbon dioxide which he exhales is absorbed by an alkali. It consists of a facepiece or mouthpiece fitted with two valves, one inspiratory, the other expiratory. To the inspiratory valve is attached a piece of corrugated tubing leading to a bel-

lows, or a bag of rubber fabric. A similar tube from the expiratory valve goes to a canister of soda lime, and another tube from there to the bellows or bag. The bag is automatically filled with oxygen from a cylinder of the compressed gas, which is carried as part of the apparatus. The automatic feed keeps the bag at all times adequately filled by admitting more oxygen whenever the bag collapses to a certain point. When the breath is inspired, oxygen is drawn from the bag; when it is expired, the breath passes through the soda lime which removes the carbon dioxide. The purified exhaled oxygen then goes into the bellows to be rein-

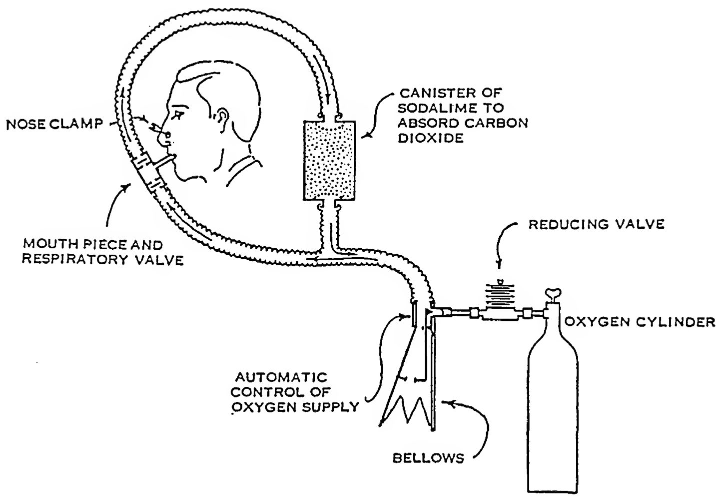


Figure 28. Schema of Self-Contained Breathing Apparatus.

spired. By this circulation oxygen is drawn from the cylinder only in amounts sufficient to replace that consumed by the wearer.

Self-contained breathing apparatus is available in two general types; one can be safely used for thirty minutes, and the other for two hours. The first weighs from fifteen to seventeen pounds, and the latter thirty to forty-five pounds. After the apparatus has been run for the specified time, the cylinder of oxygen must be replaced by a new one, and the soda lime must be renewed in the canister.

Self-contained breathing apparatus has the same general application as the hose mask. It has a marked advantage over the latter in that the wearer's movements are not restricted by a long

hose to the outer air; and he may therefore penetrate so far as he need into passages and chambers filled with an irrespirable atmosphere. But self-contained breathing apparatus has the disadvantage of being heavy and cumbersome; it is expensive, and the rubber portions deteriorate rapidly. It is a complicated piece of apparatus, and for its proper operation requires frequent inspection and adjustment. The apparatus is largely used in mine rescue work and to some extent by firemen. For purposes of exploration work and rescue over considerable distances in atmospheres deficient in oxygen, where the flame of a safety lamp is extinguished, self-contained breathing apparatus is the only means available. On the other hand, for use even in very poisonous atmospheres in which there is sufficient oxygen to support a flame, the gas mask and the canister afford not only a more practical condition for the wearer to do the work for which he has come, but also a greater degree of safety; certainly with far less liability to accident. Unsuspected defects in self-contained apparatus have cost many lives; a small unnoticed crack in one of the rubber parts imposes the penalty of death. No one should ever attempt to use this form of apparatus unless he has been thoroughly trained in its use and knows that his particular apparatus is in perfect order.

Treatment of Acute Poisoning by Noxious Gases.

The proper first-aid treatment of poisoning by noxious gases and vapors is the most important step in saving the life of the man who has been gassed; his life is often in the hands of the first arrival and the outcome depends upon the practice of the proper procedures. The doctor who treats the patient after he is taken to the hospital has far less influence on the final outcome.

Rescue.

The first step is to remove the man from the contaminated atmosphere, and to bring him as rapidly as is possible into uncontaminated and preferably warm air.

A warning is necessary at this point: The rescuer must not breathe the gas himself even for a short time. No one is immune to the action of noxious gases. The well-intentioned rescuer who

walks into an atmosphere of gas and succumbs gives no assistance to the original victim and merely adds to the work of subsequent rescuers. His action is similar to the common occurrence where a man, who himself cannot swim, jumps into deep water because he sees another man drowning. Such procedures are not heroic; they are silly. There are indeed occasional conditions in which it is possible to enter a short distance into a gas contaminated air and to drag out an unconscious man; but the rescuer should not attempt this without having a line tied round him and held by some one outside. It is usually wiser to open the doors and windows from the outside, and to allow fresh air to sweep the gas from the room before the rescue is made.

The proper procedure for rescue, however, consists in the wearing of a suitable gas mask, hose mask, or (if fully trained in its use) a self-contained breathing apparatus, together with a belt and safety line.

First-aid Treatment.

The victim should be removed from the poisonous atmosphere and placed in fresh, but not cold, air. In cold weather indoor air is preferable to outdoors. Chilling should be carefully avoided after any form of gassing, as it greatly increases the liability to subsequent pneumonia. The victim should be wrapped in blankets. Hot-water bottles and heated bricks are often recommended, but they are more dangerous than beneficial in the hands of the overzealous; a man does not complain of being burned while he is unconscious, but the burns that result from hot-water bottles or other heated objects placed next to the skin are in many cases the most serious sequel to the gassing.

Artificial Respiration.

Acute poisoning by any one of the asphyxiants leads to respiratory failure. This is true also of the majority of the volatile drugs and drug-like substances. Whenever breathing has ceased for this reason, artificial respiration should be started at once by the prone pressure method. The procedure of the prone pressure, or Schafer method, is as follows:

(1) Lay the patient on his belly, one arm extended directly

overhead, the other bent at the elbow, with the face turned to one side and resting on the hand or forearm, so that the nose and mouth are free for breathing.

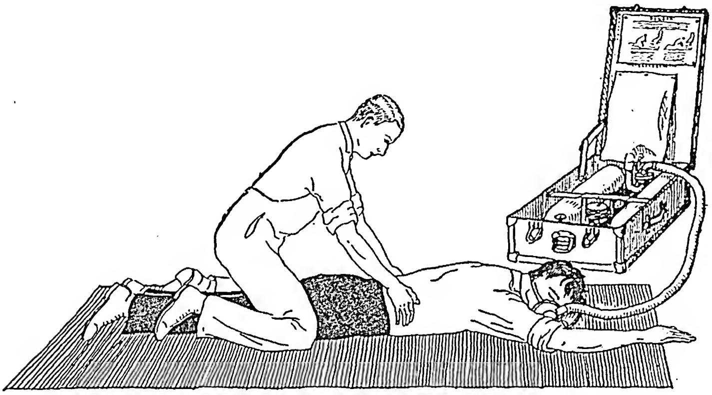


Figure 29. Artificial Respiration by the Prone Pressure Method—Position 1.

The artificial respiration is being given here in conjunction with the inhalation of oxygen and carbon dioxide by means of the H-H inhalator. The return of spontaneous breathing is expedited by the inhalation.

(2) Kneel straddling the patient's hips, with your knees just below the patient's hipbones or opening of pants pockets. Place the palms of your hands on the small of the patient's back with

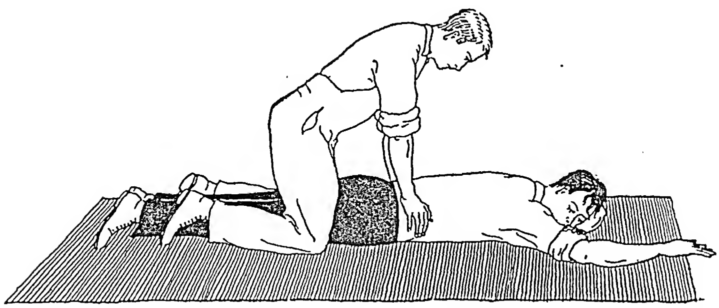


Figure 30. Artificial Respiration by the Prone Pressure Method—Position 2.

fingers over the ribs; the little finger just touching the lowest rib, the thumb alongside of the fingers; the tips of the fingers just out of sight.

(3) While counting one, two, and with the arms held straight,

swing forward slowly, so that the weight of your body is gradually, but not violently, brought to bear upon the patient. This act should take from two to three seconds.

(4) While counting three, swing backward so as to remove the pressure.

(5) While counting four, five, rest.

(6) Repeat these operations deliberately, swinging forward and backward twelve to fifteen times a minute, thus making a complete respiration in four or five seconds.

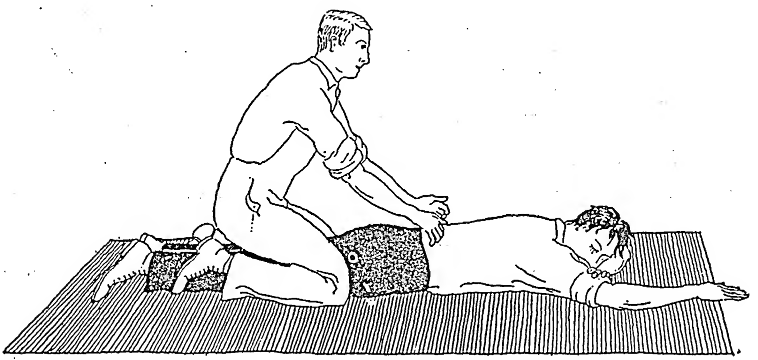


Figure 31. Artificial Respiration by the Prone Pressure Method—Position 3.

(7) As soon as artificial respiration has been started and while it is being continued, an assistant should loosen all tight clothing about the patient's neck, chest, or waist and wrap the patient warmly with a blanket.

(8) Continue artificial respiration without interruption until natural breathing is restored, if necessary for several hours, or until a physician declares *rigor mortis* (stiffening of the body) has set in. Do not stop merely because he says the patient is dead; you may be able to revive him. If natural breathing stops after being restored, use this method of resuscitation again.

Manual Methods Contrasted with Mechanical Devices.

There are several types of apparatus designed to give artificial respiration. In this country the most prominent two are the pulmotor and lungmotor. Both are inferior to the manual method of artificial respiration in their effects on the patient.

Both require a greater degree of training and experience than does the manual method. They have also the disadvantage that they are rarely on the spot when needed. The time which elapses between failure of respiration and the stopping of the heart is at the most only ten minutes, usually six, and often less. Time is the most essential factor in resuscitation; every minute lost after breathing has stopped and before artificial respiration is begun decreases the chance of recovery. Within ten minutes at most, more probably within five or less, the last chance is lost. Manual artificial respiration can be started in a few seconds by the first person who arrives at the spot where a man has been gassed. By contrast it takes many minutes to unpack, adjust, and start the mechanical devices, even in the rare instances when they are at hand. Usually they are at some distance and many minutes are lost in bringing them to the spot. Instead of immediately initiating manual artificial respiration, the rescuer waits for the device to arrive; the patient in the meantime dies. The greatest objection, however, to mechanical devices is the fact that when reliance is placed upon them general training in the prone pressure method is discouraged.

It is not necessary or beneficial to the patient, but rather the reverse, to apply artificial respiration to a man who is still breathing. Nevertheless, it is a common practice to put the pulmotor and lungmotor on such cases. Most men who are gassed by carbon monoxide, and who are still breathing when rescued, would recover spontaneously. But if a pulmotor or lungmotor or other mechanical device is brought, even an hour or two after the gassing, it is applied; then the claim is made in the newspapers that "the victim was resuscitated" by the apparatus. Their reputation for saving life is almost wholly derived from this type of pseudo resuscitation, aided by sensational publicity in the press and active propaganda. These devices have in fact done far more harm than good, and have led to the loss of many more lives than they have ever saved. Their use should be discouraged.

Treatment by Inhalation of Oxygen and Carbon Dioxide.

The inhalation of a mixture of 94 per cent of oxygen and 5 per cent of carbon dioxide after poisoning by the noxious gases and

vapors greatly assists in the restoration of normal breathing and hastens the elimination of volatile or gaseous substances which have been absorbed. The carbon dioxide in the mixture stimulates breathing. The inhalation of dilute carbon dioxide influences the respiratory center in exactly the same way as the increased carbon dioxide production resulting from exercise. There is this difference, however, between the increased volume of air resulting from exercise and from the inhalation of carbon dioxide: The development of carbon dioxide in the body by exercise necessitates the utilization of oxygen from the blood, a condition which is fatal in carbon-monoxide poisoning; the inhalation of

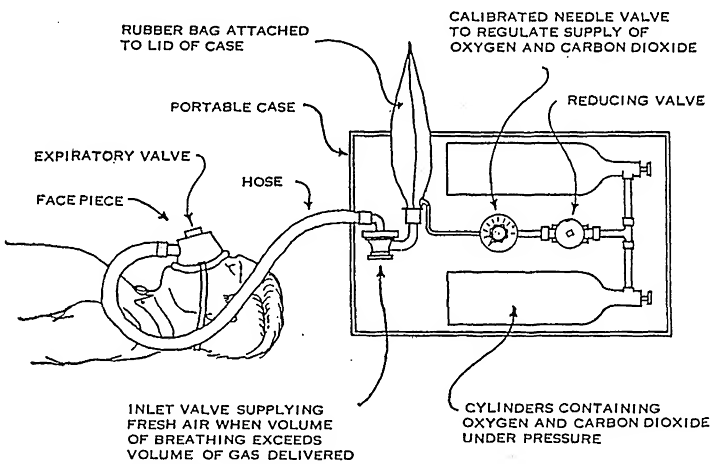


Figure 32. SCHEMA OF THE H-H INHALATOR.

dilute carbon dioxide stimulates the breathing but involves no draft on the supply of oxygen. When oxygen is used in combination with dilute carbon dioxide the displacing action which it exerts upon the carbon monoxide in the blood is brought into play in the most effective manner.

The inhalation of oxygen plus carbon dioxide does not take the place of artificial respiration. If breathing has stopped, manual artificial respiration should be administered. The return of spontaneous breathing is hastened, however, if inhalation of the oxygen-carbon dioxide mixture is given while the artificial respiration is being carried out. In order to be fully effective the inhalation should be given as soon after the gassing as possible.

If the person who has been gassed lives for three or four hours the greater part of the carbon monoxide or other gaseous or volatile substances in the blood are eliminated even when air alone is breathed. Thereafter treatment by inhalation is of less benefit. The main purpose of the inhalation of carbon dioxide and oxygen is to attain in twenty or thirty minutes the same degree of elimination of these substances as would be reached in three or four hours of elimination unassisted by inhalation. This treatment is particularly beneficial in poisoning by carbon monoxide, but is applicable also to poisoning by other gaseous and volatile substances. An especially designed inhalator must be used for the administration of the oxygen and carbon-dioxide mixture—the so-called H-H Inhalator.

CHAPTER XI

THE URINARY SYSTEM AND ITS DISORDERS

Waste Substances of the Body.

The vital activity of protoplasm, the utilization of energy from food material, in fact, all the processes of the body, result in waste substances or end products, which must then be eliminated from the body. During the combustion of carbohydrates and fats, carbon dioxide is formed. The combustion of proteins produces, in addition to this end product, urea and the salts of sulphuric and phosphoric acid. The respiratory system and the urinary system are the main excretory organs through which these substances are eliminated. The eliminative functions of the lungs and of the kidneys are complementary. The lungs are the channel of egress for gaseous substances; the kidneys are the channel of egress for solid substance in solution. Carbon dioxide and some water are eliminated through the lungs; urea, water, and inorganic salts are eliminated through the kidneys.

In addition to the two main excretory systems, there are also two minor excretory systems—the skin and the alimentary tract. The skin assists the excretory activities of the kidneys; sweat carries in solution solid wastes. The excretion of solid waste through the skin is, however, a minor function in comparison with its activity in dissipating the heat generated in the body. The alimentary tract is the channel of egress for a small amount of inorganic salts such as iron and calcium. The fecal matter, aside from these additions, is not a waste product. It is detritus—material in the food which is not digestible and bacteria which have grown in the intestines.

Elimination Through the Kidneys.

The substances eliminated through the urinary system come directly from the blood which flows through the kidneys. The kidneys exercise both a selective and regulatory activity in respect to these substances. Urea, for example, is selected from among

the other constituents of the blood and is removed as completely as possible. Other substances, which are necessary to the functioning of the body and are normal constituents of the blood, are eliminated through the urine only when they exceed in amount some definite normal concentration. Elimination through the kidneys thus serves not only to remove true waste, but also plays a large part in maintaining uniform concentrations of the normal constituents of the blood.

The elimination of sugar (dextrose) through the kidneys in diabetes is an example of this regulatory activity. Normally there is no appreciable amount of sugar in the urine, but when the concentration of sugar in the blood exceeds the normal amount, about one-tenth of 1 per cent, the excess tends to pass into the urine. The concentration of sugar in the blood is thus prevented from rising excessively (see Chapter IV). The excretion of acid and basic materials through the kidneys is similarly regulated and maintains the normal balance of alkali and acid in the blood. This balance is an essential part of the regulation of breathing to the rate of carbon-dioxide production (see Chapter VIII).

The regulation of the excretion of alkaline and acid substances by the kidneys is shown in the variations in the reaction of the urine. The urine may be either alkaline or acid, depending upon the nature of the diet. When the diet is composed largely of vegetables, the urine is alkaline, for vegetables contain an abundance of alkaline salts. This is the case even with acid fruits, for the organic acids such as citric and tartaric acid are oxidized to carbonates in the body. From a meat diet an acid urine results, for the combustion of protein produces an excess of inorganic acids such as sulphuric and phosphoric, which are eliminated through the urine. This is usually the case also from a mixed diet; and it is always the case in starvation.

Structure of the Urinary System.

The urinary system consists of the kidneys, ureters, bladder, and urethra. The kidneys are large glands in which water and solids in solution are separated from the blood. The urine thus formed is conveyed by the ureters to the bladder. The bladder is

a distensible receptacle in which the urine is temporarily stored. The urethra is the passage through which the urine is discharged when the sphincter of the bladder is relaxed.

The Kidneys.

The kidneys are placed one on each side of the spinal column and rest upon the muscles of the back or loin. The lowest ribs are approximately on a line with the middle of the kidneys. The

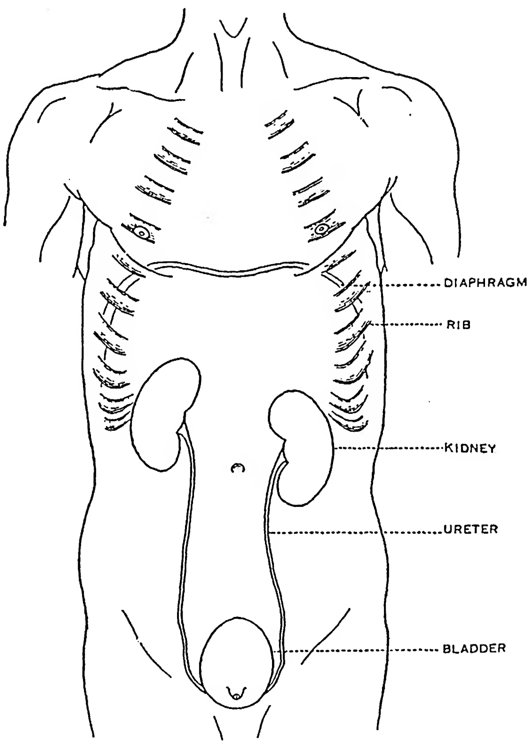


Figure 33. POSITION OF KIDNEYS, URETERS, AND BLADDER.

kidneys are shaped like beans. The depressed portion of each, corresponding to the point at which the bean is attached to the pod, faces toward the spine. It is at this point that the blood vessels and ureter join the kidney.

The kidney of an adult weighs from 120 to 150 grams (about one-quarter pound); it is of a brownish red color, and is covered by a firm capsule of connective tissue. The small adrenal glands

are placed just above the kidneys and these together with the kidneys are surrounded with fat. The kidneys are supported in place by layers of connective tissue which run along the back, but there are no bands or membranes attached to the capsules to hold them firmly in position. Occasionally one of the kidneys, usually the right, becomes loose and movable, a condition called "floating kidney." As a rule no disturbance results unless the ureter becomes kinked or compressed, in which case the urine is dammed back in the kidney and upper end of the ureter. The distension

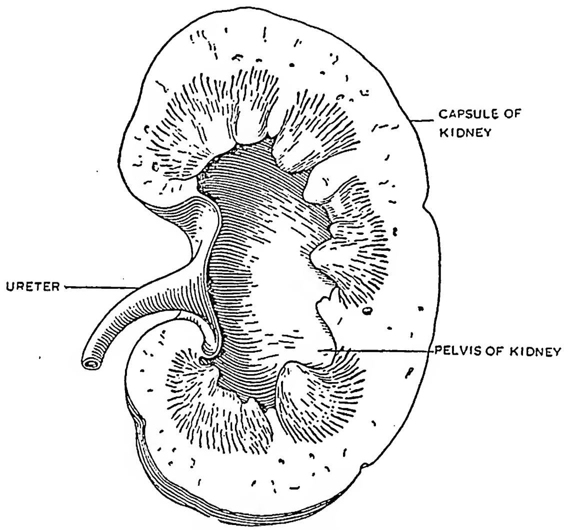


Figure 34. LONGITUDINAL SECTION OF KIDNEY.

of these structures gives rise to severe pain called renal colic.

The ureter widens out like a funnel at the point of attachment to the kidney. A space is hollowed out inside the kidney to accommodate this widened end. A great number of minute tubes open into this space. These tubules radiate toward the surface of the kidney. At their outer ends they are widened and convoluted; at the tip of each is a minute bulb, the glomerulus, surrounding a coil of small blood vessels.

Secretion of Urine.

The secretion of urine involves three phases in the activity of the kidney. Water and dissolved substances in the blood are first

filtered off. From this filtrate a considerable part of the dissolved substances and part of the water are reabsorbed into the blood. At the same time additional waste materials are secreted from the blood into the concentrated filtrate.

The primary filtration of water and solids occurs in the bulbs or glomeruli at the end of the kidney tubules. Fluid exudes through the walls of the capillaries of the glomeruli as it does from all other capillaries in the body as described in connection

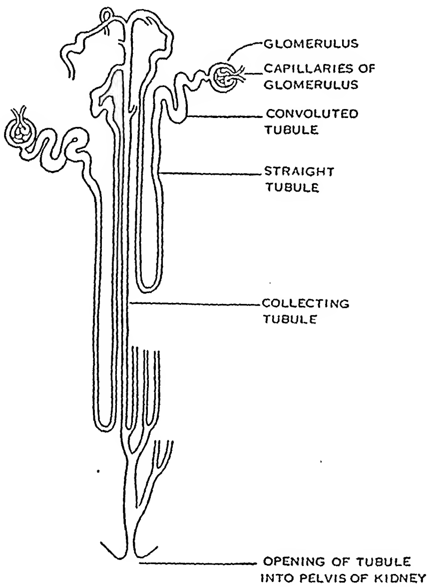


Figure 35. Schema of Urinary Tubule and Glomerulus.

with lymph formation. Protein does not pass through the walls of the capillaries. The fluid received by the bulbs from the capillaries is water containing salts, sugar, urea, amino acids, and all the other soluble constituents of the blood in the same proportion in which they are found in the blood. It is necessary to pass a large amount of fluid in order to carry away the waste materials from the blood by the process of simple filtration. In addition, the filtrate contains a certain amount of foodstuffs, such as sugar and salts, needed for the maintenance of the body. These useful materials are salvaged by reabsorption from the filtrate as it passes through the first portion of the tubules leading from the glomeruli.

In addition to the selective absorption of water, salts, and sugar, it is probable that the kidney tubules also actively secrete material into the concentrated filtrate. The cells along the tubes are probably able to secrete urea and similar waste substances, and thus to reduce the concentration of these substances in the blood to a lower level than could be accomplished by filtration alone. In animals living on land a large part of the water is also absorbed from the filtrate, so that the volume of urine voided is much less than the amount of fluid filtered off from the blood in the glomeruli. The urine, therefore, may have a higher specific gravity than the blood. In aquatic and amphibian forms of life this saving of water is not essential; a frog passes his weight or more of urine each day. In birds a further saving of water is brought about by emptying the urine into the lower part of the large intestine, where the water is absorbed, so that the bird's urine is a whitish paste.

Rate of Secretion.

The quantity of urine secreted in twenty-four hours is variable; the average volume is one and one-half to two quarts. The minimal quantity of fluid necessary to carry away the waste in solution is comparatively small. The lowest level of secretion occurs during exertion under hot surroundings; under such circumstances the loss of water through the skin is incompletely compensated by the amount of water drunk and the concentration of the urine is indicated by its dark color. On the other hand, the quantity of urine may be increased to eight or ten quarts per day by drinking excessive quantities of fluid or from disturbances in the water regulation of the body.

The rate of secretion of urine is influenced by three factors: (1) the supply of water in the body, (2) the volume or pressure of the blood passing through the kidneys, and (3) the activity of the secretory and absorptive processes in the kidneys. Thus the rate of secretion increases as the supply of water in the body rises from the ingestion of fluid, and diminishes as the supply of water falls as a result of the loss through the kidneys, through the skin as sweat, or from the digestive tract, as in diarrhea. The secretion of urine is also increased when the rate of the blood

flow through the kidneys is augmented. Thus the rise in arterial pressure caused by mental concentration, worry, or anxiety increases the rate at which urine is formed. Chilling of the skin also increases the flow of blood to the kidneys, and hence the volume of urine. Some substances, notably caffeine of coffee and theobromine of tea, increase the rate of urine formation. These substances are called diuretics. They act by increasing the flow of blood to the kidneys or by stimulating directly the secretory activity.

Suppression of Urine.

The secretion of urine may cease as a result of disease. Obstruction of the ureters by stones or tumors results in such a suppression; more often the obstruction occurs in only one ureter and the opposite kidney carries on the function of both. In severe injury to the kidney from poisoning by bichloride of mercury, the flow of urine may be stopped entirely. The usual duration of life after complete suppression of the flow is from eight to fourteen days. At first there is no particular illness, but after a few days headache and weakness develop, and finally unconsciousness and death.

Albumin in the Urine.

Protein does not pass through the walls of the capillaries surrounding the renal tubules and therefore does not normally appear in the urine. Under certain circumstances, however, protein or, as it is usually called, albumin finds its way into the urine. The appearance of albumin always arouses a suspicion of disease in the kidneys. Nevertheless, albumin may appear in the urine, even when the kidneys are normal, after violent muscular exertion such as a rowing race, football game, or a long-distance running contest. Ordinarily the passage of albumin ceases after a day or two, but in some instances it may continue for a week and in exceptional cases even longer. Albumin may also appear in the urine after prolonged exposure to cold. It sometimes appears in the urine of young people, but usually it is passed only during the time they are standing, so that it appears in the urine secreted during the day, but does not appear in the urine secreted at night.

This positional effect apparently does not arise from any defect of the kidneys; it is often associated with improper standing posture in which the lower part of the back is curved forward to an exaggerated degree. The albumin usually disappears from the urine when adult years are reached; and in some cases it may be stopped earlier by correcting the curvature of the back with braces or by exercises.

In disease of the kidneys the albumin may appear not only in the dissolved form, but also as solid particles which are visible under the microscope. These bits of protein material are shaped like the inside of the urinary tubules in which they are formed; for that reason they are known as "casts."

Albumin in the urine cannot be detected by mere inspection; a chemical test is necessary. Neither cloudiness of the urine nor formation of sediment after the urine has stood are indications of albumin. Such sediments are usually phosphates or oxalates which precipitate readily out of the urine. These precipitates are not significant of disease; although the literature of some patent medicines states that these perfectly normal precipitates are grave indications of disease which are, of course, "curable" by the patent medicine.

Blood in the Urine.

When blood, or the products of disintegrated hemoglobin, appear in the urine, it is colored either dark red or a smoky black. Like albumin, blood in the urine is not always a sign of disease in the kidneys. Occasionally the kidneys bleed, just as the nose does, from no apparent cause. A severe blow over the back may likewise cause bleeding from the kidneys. Blood may appear in the urine as a result of inflammation in the urinary passages arising from infection, or from the irritation due to stones. When the red blood corpuscles are disintegrated in large amounts by disease or poison, the liberated hemoglobin is excreted through the kidneys and appears in the urine as in "black-water fever," a severe form of malaria. Finally, blood may appear in the urine as a result of inflammation of the kidneys due either to poisons or to acute Bright's disease; it is then of very serious significance.

Nephritis.

Inflammation of the kidney, or nephritis, is often called Bright's disease, after its discoverer. The condition may be either acute or chronic. Acute nephritis is caused by substances which irritate and inflame the kidneys or which disturb their circulation. Poisonous substances such as bichloride of mercury, turpentine, Spanish fly, and carbolic acid irritate the kidneys, and in severe poisoning causes acute nephritis. Deaths from bichloride poisoning, which occur about two weeks after the ingestion of the poison, result from the damage to the kidneys. Although the action of the bichloride upon the digestive tract is acutely painful, the subsequent inflammation of the kidneys is not. The mistaken belief that bichloride poisoning results in painless death, an error spread by the newspapers some ten years ago, led to a vogue for this poison as a means of suicide. A more unpleasant poison could hardly be found unless it were its predecessor in favor, the equally corrosive carbolic acid.

Acute Nephritis.

Severe exposure to cold and wet is one of the commonest causes of acute nephritis. It is particularly liable to follow exposure after drinking alcohol. The chilling of the skin acts upon the circulation in the kidneys. Even a mild degree of chilling is followed by an increase in the flow of urine due to the increased blood supply; in severe chilling the kidneys are damaged by the congestion which results.

Acute nephritis may be caused by the poison which results from infections and particularly from scarlet fever. Less commonly it follows typhoid fever, measles, diphtheria, and tonsilitis. A similar condition occasionally results from the absorption of toxic material from extensive burns.

Pregnancy is occasionally complicated by the development of acute nephritis. It occurs in women whose kidneys are not able to support the burden added to the excretory system by the pregnancy. Frequent examination of the urine during pregnancy is important, for the appearance of albumin is a warning of a failure of the kidneys; it is still more important as an indication of the

development of another condition known as eclampsia, which is even more serious in pregnancy than is nephritis. Although eclampsia is not primarily a disease of the kidneys, its presence is usually preceded by the appearance of albumin in the urine.

In acute nephritis the urine may be entirely suppressed, but more commonly it is scanty, highly colored, and contains blood and albumin. Only four or five ounces of urine may be passed in twenty-four hours. The damage to the kidney may be followed by dropsy, which is shown in swelling of the ankles and eyelids and by anemia, which gives to the skin a peculiar waxy pallor. Occasionally convulsions and other disturbances occur. Acute nephritis may result in death; more often, however, there is more or less complete recovery. Under proper treatment the urine gradually returns to a normal amount and the albumin disappears; in other cases the damage to the kidneys is permanent and the disease becomes chronic.

Chronic Nephritis.

Chronic nephritis appears in a variety of types which differ according to the portion of the kidneys which is most markedly diseased. The various types are broadly divided into two groups: (1) those in which the secretory structure of the kidney is diseased; and (2) those in which the main change is in the blood vessels and the tissue between the tubules. The first type is by far the more serious. It occurs most commonly in young adults as a sequel to acute Bright's disease, although it may develop independently of this condition and from unknown causes. It may also appear as a result of chronic infection (of teeth and tonsils, etc.), and from syphilis; it is believed that habitual alcoholism may also be a contributing factor. The symptoms of this type of chronic nephritis are much like those of the acute disease. The urine is as a rule diminished in volume and contains an abundance of albumin. Dropsy is a regular feature. The face often has an appearance distinctive of the disease; the complexion is pasty and pale, the skin is puffy, particularly about the eyes.

The second type of chronic nephritis is due primarily to a hardening of the tissue surrounding the secretory tubules. It gives

rise to none of the bodily changes common to the first type. There is no dropsy, the urine is over-abundant rather than scanty, and albumin may be entirely absent or present only in traces. The chief disturbances caused by the disease are in the circulatory system; they are increased arterial pressure, hardened arteries, and enlarged heart. This type of chronic nephritis is a factor in the "cardio-vascular-renal syndrome" discussed under arterial hypertension. To some extent the hardening of the kidney is a result of age similar to hardening of the arteries. In the aged, chronic nephritis develops along with hardening of the arteries; as a rule, no indication of the changes in the kidneys appears other than an increase in the amount of urine secreted, which necessitates micturition one or more times during the night.

It is not definitely known how the circulatory system is altered by the hardening of the kidneys, but an ingenious mechanical conception has been suggested. According to this view the volume of blood flowing through the kidneys at any time is determined by the amount of materials which are present in the blood and need to be passed out through the kidneys. When the kidneys are hardened and the capillaries shrunken, the pressure of blood in the arteries must be raised in order to force the necessary volume of blood through the kidneys. As a result of the increased arterial pressure the heart enlarges and the arteries harden.

Chronic nephritis is incurable; the anatomical condition upon which it depends is as much beyond the reach of treatment as, for example, is gray hair. The condition is, however, compatible with the enjoyment of life for many years. The combination of symptoms so common in men past middle age, of increased arterial pressure, hardened arteries, and increased flow of urine does not lead to immediate death, nor does it necessarily interfere with the pursuit of an active life so long as proper care is taken. Such care consists of moderate and regular exercise, avoidance of over-eating, particularly of meat, freedom from worry and, if possible, residence in an equable climate.

The yearly medical examination now recommended for everyone has as its main object the early discovery of the changes in the circulatory system and kidneys which indicate the development

of chronic nephritis. Although the damage cannot be remedied, its progress can be retarded; for this reason the early detection of the condition is important.

The Ureters, Bladder and Urethra.

The ureters are slender tubes 25 to 30 centimeters (10 to 12 inches) long, one of which extends from each kidney to the bladder. The urine is carried through the ureters in drops by a movement of the walls analogous to that which carries the food through the esophagus and intestines.

The bladder is a reservoir for the collection of urine. The flow of urine from the kidneys is practically continuous, although the rate varies. The bladder collects this flow, and allows the ejection of the accumulation at convenient intervals; an advantage similar to that afforded by the stomach in the taking of food and by the large intestine in the ejection of the feces.

The bladder lies beneath the peritoneum of the lower part of the abdominal cavity near the front wall. The ureters and urethra open into it on its under surface. This part of the bladder is held firmly in place by ligaments; the unattached upper side is the distensible portion. (See Figure 70.)

The size of the bladder depends upon the volume of its contents. Its capacity is variable. The point of distension which ordinarily induces a persistent desire for evacuation is determined by the habits of the individual. The figures for this capacity range from 180 to 720 cubic centimeters (6 to 24 ounces) with about 500 cubic centimeters (1 pint) as an average. The bladder is stretched and its capacity greatly increased by habitually allowing a large amount of fluid to accumulate before evacuation. Under abnormal conditions the bladder may be forced to hold three or four liters.

The urethra, which is the canal conveying the urine from the bladder to the exterior of the body, is about one and one-half inches long in the female and much longer in the male. In the male it is modified to function as a part of the sexual apparatus.

Evacuation of the Bladder.

The flow of urine through the urethra is controlled by two muscular valves. The first of these valves is formed by a thick-

ening of the muscular wall of the bladder surrounding the opening into the urethra; the second valve is a separate muscle which encircles the urethra after it has left the bladder. The first valve is controlled by an automatic or reflex mechanism and is not under voluntary control. When the bladder has filled to a certain degree or rather to certain pressure, the valve opens and allows the urine to pass into the urethra. This passage of the urine into the first part of the urethra gives rise to a conscious desire to urinate. If no obstacle is presented the bladder empties itself by the contraction of the muscular walls. The emptying of the bladder may be prevented by the second muscular valve about the urethra which is under the control of the will.

The pressure in the bladder which initiates the reflex part of micturition is influenced by two factors—the volume of urine collected and the tenseness of the walls of the bladder. The bladder is a muscular organ and its tenseness is varied by the activity of the nervous system. The bladder is made more tense by excitement or anxiety; as a result the desire to micturate arises even when only a small amount of fluid has collected. If the micturition is prevented by the action of the valve which is under voluntary control, the bladder may subsequently relax, and as it relaxes the involuntary valve closes. The desire to micturate then passes off until the fluid has again collected in sufficient quantity to raise the pressure.

Irritation of the urethra or of the bladder near the urethral opening gives rise to the desire to micturate even though the bladder is not distended. Irritant condiments such as ginger, mustard, or pepper, of which the essential oils are eliminated through the urine, may irritate the bladder. The irritation may also arise from bacterial infection in the bladder. The infection enters either by way of the kidneys or as an ascending infection from the urethra. Inflammation of the bladder is known as cystitis.

Enlargement of the prostate gland, a stone in the bladder, or a stricture of the urethra (usually from gonorrhea) may prevent the bladder from emptying. The prostate gland is an accessory organ of the male generative apparatus. The urethra passes through the substance of this gland. The gland often enlarges in

old men, compresses the urethra, and thus obstructs the flow of urine. It is then necessary to pass a rubber or enameled linen tube, called a catheter, through the urethra so as to withdraw the urine. The continual use of the catheter is annoying and frequently leads to cystitis. The obstruction can be relieved by removing the prostate gland by surgical operation.

Stone in the Bladder.

Stones sometimes form in the bladder; they are composed of the salts of uric acid and of the oxalate and phosphate of calcium. In some instances the stone forms as an incrustation on a foreign substance in the bladder, a blood clot, clumps of bacteria, or objects introduced from the outside. More often, the stone is formed entirely of material precipitated from the urine. The factors predisposing to this precipitation are unknown; the fact that the condition is more prevalent in some countries than in others suggests that it may be dietary. The stone often forms in the upper end of a ureter, and in passing down to the bladder gives rise to intense pain like that of gallstones. The stone thus formed may be very small, in which case it is passed in the urine as "gravel"; or it may lodge in the bladder and grow to a large size by the deposit of material on its surface. Ultimately the stone irritates the bladder or obstructs the flow of the urine. Stones are removed from the bladder by surgical operation; either the bladder is opened or the stone is crushed by a clamp-like instrument passed through the urethra. "Cutting for the stone" is a very ancient surgical operation.

Stricture.

The walls of the urethra are ordinarily in apposition; the flow of urine spreads the walls apart and forms a canal. A stricture prevents dilatation and so obstructs the flow of urine. In acute gonorrhea the mucous membrane of the urethra may become swollen to such an extent as to cause stricture. Or as a result of the healing of the disease the walls of the urethra may be scarred and hardened, so that they dilate to only a limited extent. The partial obstruction caused by scarring may become complete for a time as a result of exposure to wet or cold, especially after drink-

ing alcohol. A blow on the urethra, or trauma from riding on horseback, may cause a temporary stricture even in men who have had no previous inflammation of the canal. Such temporary stricture may usually be relieved by a hot bath and emptying the bowels; otherwise it is necessary to pass a catheter to remove the urine which has collected.

CHAPTER XII

THE SKIN

THE excretion of solid substances through the skin is a minor function; no serious effects would follow its complete abolition, for the kidneys could normally carry the added burden. The most important function of the skin is the dissipation of heat. If the loss of heat is prevented over the entire skin area, an intense fever develops and death follows in a short time. The process of heat dissipation from the skin is regulated by the nervous system, which controls the activity of the blood vessels and sweat glands in the skin (see Chapter XX). Another important function of the skin is that of protection; as the skin is the organ of the body most intimately in contact with the environment, it is subject to many minor and some major insults.

Protective Function of the Skin.

The skin covers the surface of the body and forms a protecting coat over the more delicate tissues beneath. It is impermeable to water and this prevents the body from drying up, as it would if the unprotected tissues were exposed to the air. The same waterproof characteristic prevents the passage into the body of substances applied to the skin; many chemicals dissolved in water are rapidly absorbed into the blood if they are applied to areas from which the skin has been removed. Even more important is the fact that if it is unbroken, the skin prevents the entrance of most of the vast hosts of bacteria which constantly come in contact with it.

Structure of the Skin.

The skin, like all the other organs of the body, is made up of a matrix of connective tissue containing blood vessels and lymphatics and forming a support for the special cells which characterize the tissue, in this case epithelial cells. The deepest layer of the skin consists of a sheet of connective tissue to which are confined

all of the nerves, blood vessels, and lymphatics of the skin. This layer, called the corium, serves to nourish the layer of epithelial cells which rests upon it. The area of corium in contact with the epithelial cells is increased by its irregular contour. It rises in small hills or papillæ which project into the epithelial layer. Ridges of the papillæ form the small lines seen on the palmar surface of the hands. The under surface of the corium is infiltrated with fat, upon a layer of which substance the skin rests. The corium is the layer of the skin which, when tanned, forms leather.

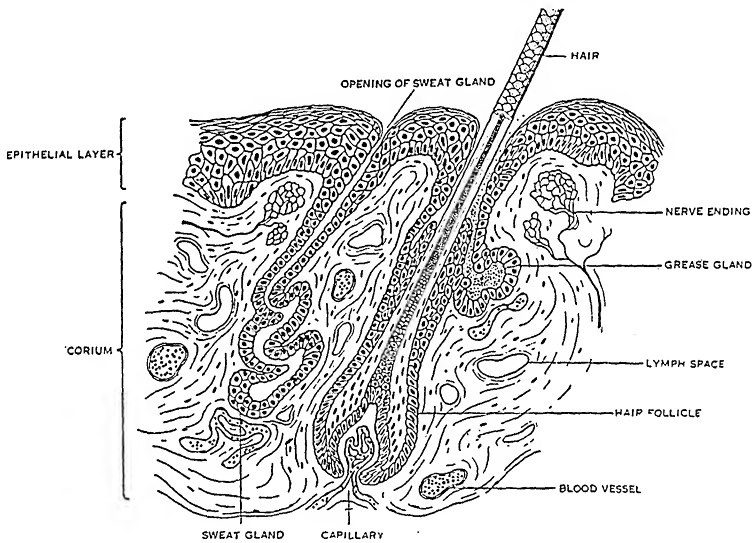


Figure 36. Section Through Skin.

Several layers of epithelial cells rest upon the corium. By gently scratching the skin with a pin a very appreciable furrow may be made before the lymph or blood from the corium appears; this shows the absence of these fluids in the epithelial layers.

The layer of epithelial cells in immediate contact with the corium and nearest to the supply of nourishment, grows actively and continually produces new cells. As these cells are pushed outward by this growth, their shape and composition are gradually altered. They are flattened and the material of which they are composed changes into a hard substance known as keratin. Keratin is the

material of which are composed not only the outer layer of the skin, but also the hairs and the finger and toe nails of man, and the horns and hoofs of other animals. The epithelial cells in which this alteration of composition has taken place are dead. They form a coating of resistant scales over the surface of the skin. These dead cells are gradually scruffed off and continually replaced by the formation and transformation of new cells.

The skin varies in thickness in different parts of the body, ranging approximately from .5 to 4 millimeters (0.02 to 0.16 of an inch). That on the palms of the hand and soles of the feet, and on the shoulders and back of the neck, is the thickest. The epithelial layer of the skin is much thinner than the corium; although varying somewhat, it averages about 0.1 millimeter in thickness.

The deeper layers of the epithelial cells contain pigment. The amount of this pigment varies with the inheritance of the individual and to some extent with his exposure to sunlight. The color of the skin is a blending of its own pale hornlike color with the tint of the pigment and the tint of the blood in the vessels of the corium, which show through the epithelial layer. When the vessels are empty, as after death, or constricted, as the result of some emotion, the true color of the skin is seen. Where the blood vessels in the corium are numerous and the overlying strata of epithelium thin, the skin exhibits the pronounced rosy color of the lips, cheeks, and ears. On the contrary, where the vessels are less numerous the skin is of a paler tint, as in the limbs and trunk; but even there the skin may become red from the dilatation of the vessels due to heat or irritation.

Unless it is tightly bound to the underlying tissue, as it is over the ears, palms, and toes, the skin is rather freely movable. It is also elastic, to which is due the smoothness of the skin in spite of temporary displacement and stretching by the movements of the joints and muscles. This smoothness of the skin is particularly conspicuous in early life. With advancing age the elasticity of the connective tissue decreases, just as it does in the walls of the arteries. Folds in the skin are no longer effaced and wrinkles are formed.

Hair.

A hair is an outgrowth of the epithelial cells of the skin. The surface of the skin is not perforated to allow the hair to emerge, but instead is depressed into a deep pit which extends into the corium or even into the fat below. The hair grows from the bottom of this pit or follicle. There a small area of actively growing epithelial cells undergoes the same transformation as the epithelial cells on the surface. Layers of dead and modified cells are piled up, forming a column which extends above the skin as a hair.

The color of the hair is determined by pigments which are in and about the cells. The color is usually, although not always, of about the same intensity as the general skin pigmentation; that is, fair-skinned people tend to have blond hair; those who are more brown-skinned have dark hair. The shape and curvature of the hair follicle determines whether a hair is straight or curly. In the case of straight hair the follicle is straight and the shaft of the hair is circular in cross-section. Hairs that are wavy or curled come from follicles more or less bent and flattened or irregular in cross-section.

There are two types of hair on the body: one a very fine hair which covers most of the skin and is known as the lanugo hair, the down on a child's cheek; and the second a coarser type, more deeply rooted in the skin, which includes the hairs of the beard, scalp, eyebrows, eyelashes, axillæ, and pubes.

Grease Glands.

Two or more sebaceous glands are associated with each hair. These grease glands open into the sac of the hair follicle near the point where the hair emerges. A sebaceous gland is formed by an irregular outpouching of a hair follicle. The epithelial cells which line this pouch grow and degenerate, as do the epithelial cells of the surface, but instead of changing into horn they become impregnated with fatty material. This fatty secretion, together with the detritus from the degenerated cells, forms the secretion of the glands. When the outlet of a sebaceous gland is blocked, as it may be by inflammation and consequent scarring over, the secretion is not discharged; but as the growth of the

epithelial cells continues the secretion accumulates and dilates the gland. The swelling thus produced is known as a wen; and when disfiguring it can be removed by a minor surgical operation. If even a small portion of the epithelium of the glands is left the secretion continues and the wen forms again.

Sweat Glands.

The skin in practically all parts of the body contains sweat glands. The palms of the hands, where the glands are particularly numerous, contain over a thousand to the square centimeter. These glands are not associated with the hairs, although a sweat gland, like a hair follicle, is formed by an invagination or infolding of the epithelium. The long slender tube thus formed is coiled into a spiral which extends downward through the corium. The cells which line this tube do not degenerate or make a solid secretion like the sebaceous glands. They form a true gland like the salivary glands, and secrete a fluid which is derived from the blood in the vessels surrounding the lower portion of the gland. Perspiration only becomes evident as moisture upon the skin, when the rate of secretion is in excess of the rate of evaporation into the air. The secretion of sweat is varied and controlled through nerves from the central nervous system. The grease which is left by the evaporation of sweat lubricates the skin. Areas which are not supplied with hair, and hence have no sebaceous glands, receive their only lubrication from the grease of the sweat. The skin of the palms and soles is relatively poorly greased and wrinkles and whitens when soaked in hot water more rapidly than does the skin on other parts of the body.

Finger and Toe Nails.

The finger and toe nails of man correspond to the claws and hoofs of beasts. These structures are formed by the outgrowth of slightly modified horny epithelial cells. The development of a nail is much like that of a hair. At the base of the nail the skin folds back under the surface and forms a slot. This slot corresponds to the hair follicle. The epithelial cells on the lower wall of this slot form the matrix of the nail. By their growth the nail is produced. The outer limit of the matrix is marked by the

white crescent or lunula, which is seen in most persons on the thumb at least and in many on all the nails. The epithelial cells of the matrix grow and are transformed into the firm sheet of keratin of which the nail is composed.

Beyond the matrix the nail rests on the nail bed, which has no part in the growth or structure of the nail. The nail is simply pushed along the bed by the addition of substance in the matrix. The nail is held to the bed by longitudinal ridges of papillæ in the nail bed, which fit into minute grooves on the under surface of the nail.

The white spots occasionally seen in the nails are due to the presence of air between the layers of cells. They have no significance. A transverse groove indicates a period of arrest in the growth of the nail and often marks the date of some illness. A longitudinal groove indicates irregular growth in the matrix and arises either from injury of the matrix or from disease.

Variations in the Pigment of the Skin.

The pigment in the deeper layers of the epithelium forms a screen against the penetration of light. A black surface absorbs more heat than does a white one. A white man can withstand heat as well as a negro, but he has less protection against light. Some light rays are harmless, but the chemically active, actinic, or ultra-violet rays, in high concentration, kill tissues. The germicidal action of sunlight is due to the actinic rays. They are necessary to health, particularly in the growing child, but in excessive amounts they are harmful to the skin and tissues beneath it. The skin pigment varies in response to the intensity of the rays striking upon it and thus tends to some extent to regulate the amount of light which penetrates the skin.

Tan and freckles are not caused by heat. Men who work in bakeries, laundries, or other hot places may have white skins, while mountain climbers burn and freckle amid the snow and ice of high altitudes. When exposure to sunlight ceases the tan gradually disappears. Freckles, especially in the aged, often remain and may even appear on parts of the body which are not exposed to sunlight. Since the skin pigments are in the deeper layers of the epithelium, they can be removed only by stripping

off these epithelial layers. Corrosive chemicals are sometimes sold as cosmetics for this purpose.

Pigmentation of the skin may occur from causes other than exposure to light, and particularly from any long-continued inflammation of the skin. Thus repeated slight burns result in discoloration. Constant scratching of the chest and shoulders infected with body lice may lead to the stripes of pigmentation which are the characteristic sign of "vagabond's disease." A general pigmentation of the skin results from the prolonged use of arsenic. When silver nitrate is taken internally the salts of this metal may be deposited in the skin, where they are reduced by exposure to light and color the skin a dusky blue, a condition called argyrea. Areas of pigmentation either diffuse or circumscribed may occur, especially on the face, as a consequence of disease of the abdominal organs, the kidneys, liver, ovaries, or even the appendix. Similar discolorations of the skin may appear during pregnancy.

Moles are usually pigmented; but moles are more than simply pigmented area of the skin. They are growths made up of a collection of epithelial cells which are beneath the surface epithelium. It is this characteristically deep growth which distinguishes them fundamentally from the cauliflower-like growth of warts, which rise from but do not extend into the corium. Moles, particularly those which are deeply pigmented, are to be treated with caution. They are occasionally the starting points of cancers, the so-called melanotic or pigmented, and very malignant, cancers. The vast majority of moles remain simply as cosmetic blemishes, but the liability to cancerous change is greatly increased by any irritation. It is therefore advisable to have moles removed whenever they are in localities where they become frequently irritated, such, for example, as on the side of the nose in those who wear eyeglasses. Their removal should be done by a competent surgeon and not through the type of treatment often applied to warts. A mole which shows a tendency to grow, or which presents a broken surface, should be removed at once wherever located.

The pigmentation of the skin may diminish as well as increase.

Removal from sunlight leads to a bleaching of the skin through a process just the reverse of the formation of tan—the "prison pallor." In the condition known as vitiligo, or leukoderma, areas of the skin and their hair become whitened. Small, round, white spots appear in the skin, and these spots increase in size until large areas of the surface are entirely devoid of pigment. The disease has no other features or effects than the decrease in pigmentation.

Variations in the Secretion of Sweat.

Sweat is normally colorless or faintly yellow. In rare instances, however, that from the axillary region may be colored red or even blue. This discoloration is due to the presence of certain bacteria which grow about the hairs. The sweat is stained by the colored products of these bacteria. The condition is not dangerous to health; it clears up under local treatment.

There is a wide difference in the amount of sweating in different persons under comparable conditions of exertion and heat. The secretion is under the control of the nervous system; the activity varies in correspondence to the general nervous tone or emotional state of the individual. Excessive general sweating may result from systemic weakness, anemia, or other form of ill health, as do the night sweats of tubercular patients.

Excessive sweating is often limited to a small region, while the remainder of the body shows a normal reaction. Some persons sweat on the palms of the hands, on the feet, and in the axillary region even when they are chilled. Excessive sweating of the feet is often associated with whitening and irritation of the skin, particularly between the toes, which permits the growth of bacteria on the softened skin. These organisms produce an unpleasant odor, a condition known as bromidrosis.

Excessive sweating of the feet is not only annoying; it may result in incapacity for certain occupations, because of the tenderness of the feet. It is a serious problem in the army. The yielding of the plantar arches which leads to flat feet is often accompanied by excessive sweating.

There are a variety of toilet preparations intended to relieve local sweating. These are for the most part astringents such as

aluminum acetate and tannic acid. As a rule these cosmetics are not harmful when used with discretion, and they are often not effective. In mild cases of sweating of the feet it usually suffices to wash them twice a day, to change the socks every day, or oftener, and before putting them on to dust into them some mild antiseptic powder such as boric acid. For the more serious cases of sweating of the feet, particularly if there is bromidrosis, the advice of a dermatologist should be sought, for the remedies effective in obstinate cases can be properly applied only under his direction.

The secretion of sweat is never entirely suppressed under any circumstance. In many fevers it is markedly diminished, but profuse sweating accompanies the fall to a normal temperature. In the disease ichthyosis the secretion of sweat is greatly diminished in the affected parts. In ichthyosis, or fish skin disease, the outer or horny layer of the skin grows excessively and becomes thick and scaly. In the milder forms of this disease the sufferer is conscious of it only in the colder months when the skin is dry and has a tendency to scaliness about the knees, elbows, and borders of the armpit. From this mild variety there are all degrees of the disease, up to the severe cases in which large areas of the body are covered by dark horny masses, so that the skin resembles that of a reptile rather than that of a man.

Influence of Bodily Condition upon the Skin.

As the skin is an organ of the body just as is the liver or heart, it responds to those factors of health and disease which influence other organs. The hardening of the connective tissue throughout the body, usually as a result of age, has been mentioned above as the cause for the loss of youthful appearance in the skin. In severe varicose veins the circulation in the skin is diminished over the affected area. The skin hardens, becomes scaly, and ulcers form from slight wounds. Similarly, when the flow of lymph is impeded, the skin develops into a warty hide. The disease elephantiasis derives its name from the skin change of this character. The skin of the legs of the man affected resembles somewhat that of an elephant. It is due to the plugging of the lymphatics of the

legs by an animal parasite. A like condition on the legs, although much milder, sometimes results from wearing tight and narrow garters.

Some drugs lead to changes in the skin. The rashes and eruptions which accompany such infectious diseases as scarlet fever, smallpox, chicken pox, typhoid fever, and syphilis are simply the involvement of the skin by the disease. They are evident because the skin is exposed to the eye. Other organs of the body are also involved, and even more seriously than the skin, but the injury is not visible.

Absorption Through the Skin.

There are a few substances which penetrate the skin and which are not destroyed in the surface tissues. Such substances are absorbed into the blood. Oily substances mix with the grease of the skin and penetrate the outer layers more readily than do watery solutions. Similarly, grease solvents such as ether or gasoline penetrate more easily. A classical example of absorption through the skin is that of mercury. The finely divided metal mixed with grease was formerly rubbed on the skin in the treatment of syphilis. The grease penetrated and carried with it some of the mercury. The systemic effect was the same as that of swallowing the salts of mercury, but their irritating action on the stomach and intestines was avoided.

Chemical substances are encountered in industry, and even in our daily life, which have the property of penetrating the skin and causing poisoning. Aniline oil, the most common of these substances, is extensively used in dyeing; it is often a constituent of leather dressings and shoe polish, and has now found its way into motor fuel as an anti-knock compound. Aniline, when absorbed, combines with and alters the hemoglobin of the blood, turning it a chocolate color. One of the commonest forms of aniline poisoning by skin absorption is met with in dyeing tan shoes black with an aniline dressing. The wearing of the shoes before the aniline oil has dried out may induce poisoning and has even caused death. Nitrobenzene or artificial oil of mirbane is absorbed through the skin like aniline, and may occasion severe poisoning when it is splashed on the clothing.

Inflammation of the Superficial Layers of the Skin, or Dermatitis.

Inflammation of the superficial layers of the skin occurs when the forces or agents acting upon it overcome the resistance which it offers and kill some of the tissue. Although inflammation is initiated by this destruction of tissue, the inflammation is a process distinct from the actual destruction, and may appear some time after the tissues are killed. Thus when the skin is lightly burned the destruction of the tissue is not apparent, but inflammation develops later through the stages of reddening, swelling, and blistering. Inflammation is a reaction characteristic only of living tissue. When the skin of a dead body is burned these inflammatory changes do not occur.

A substance or force which causes inflammation is known as an irritant. Irritation in this sense signifies merely that the agent injures in some manner or kills a part of the tissues with which it comes in contact. Inflammation is identical, regardless of the agent which inflicts the injury, but the degree of the reaction depends upon the extent of the tissues injured. Therefore the appearance of inflamed areas may differ widely according to the degree to which the inflammatory process progresses. Thus a scaly inflammation, following the use of laundry soap, arises through the same process as do the redness and blisters after a burn. The distinction depends only upon the differing intensity and duration of the action of the two agents.

When an irritant is applied to the skin the first visible reaction is redness. This redness is due to the dilation of the small blood vessels in the skin. Fluid exudes from the vessels and passes into the loose tissues of the corium and between the epithelial cells. It is this exudation of fluid which causes the subsequent changes shown by the inflammation.

If the irritation is slight, only a small amount of fluid seeps between the epithelial cells. If this fluid continues to accumulate owing to continuation of the irritation, the normal growth of the epithelial cells is altered. They form into coherent masses which are cast off as scales instead of singly and insensibly, as they are from the normal skin. Inflammation from the milder forms of

irritation is thus of a scaly type, as in roughened or chapped hands.

If the amount of exudation is greater it seeps between the altered cells and makes its way to the surface. There the fluid coagulates and forms crust-like scabs over the scaly area. Under the action of more intense irritation the fluid exudes with such rapidity that the cells in the epidermis are pushed aside and little pools of fluid are formed among them. These collections of fluid are called vesicles and appear like minute blisters, although their mode of formation is somewhat different from that of a blister. White blood corpuscles often collect in the vesicles, and the otherwise clear fluid then becomes white and turbid. The name pustule is then applied, instead of vesicle. The amount of fluid exuded in the tissues may be so great that the altered cells in the outer layer of the skin are washed away. There is left then a raw surface from which drops of fluid exude.

If the irritation is intense the reaction is so acute that large amounts of fluid are thrown out into the tissues before the growth of the cells has been altered by imbibition of the fluid. The normal cells are not thrown off by the fluid, but are separated in a layer from the underlying tissues. The fluid collects between these layers and a blister or bleb is formed.

Inflammation of the outer layer of the skin, or dermatitis, often shows concurrently several phases of the phenomena here described. Thus scales and vesicles or even raw spots may appear together in the same inflamed area.

Dermatitis caused by an irritant may be complicated and aggravated by infection. Moreover, the infection does not at once disappear when the original cause of the dermatitis is detected and eliminated. A group of closely related bacteria, which from their shape and type of growth are known as staphylococci, are always found on the skin. Even the most thorough washing cannot entirely rid the surface of them. Normally these bacteria are harmless. The exudation from an inflamed surface furnishes a medium in which they can multiply rapidly. As a result of this luxuriant growth the bacteria are strengthened so that they cease to be harmless and themselves become capable of producing dermatitis.

Variation in Susceptibility to Irritation.

There is a wide difference in the degree of resistance offered by the skin of different persons against the destructive action of any irritant. This difference finds its expression in individual susceptibility to irritants. Thus some persons are acutely sensitive to the oil from poison ivy, while others are nearly immune. A soap which can be used with impunity by one may cause severe dermatitis in another. Toilet preparations intended to beautify the skin and harmless to most persons may cause marked irritation in a few persons. Even certain dyes in the clothes irritate the skin of particularly susceptible persons. Aside from individual susceptibilities there is also a greater general susceptibility in the young. The skin of an infant is very sensitive to irritation and that of a child is more susceptible than that of an adult. Likewise any decrease in the general health is accompanied by a diminution in the resistance offered by the skin.

The sweat and grease glands of the skin form part of its defense, so that variation in their activity may affect the susceptibility to irritation. Profuse perspiration retains irritating dusts and also assists in their solution. An increased activity of the grease glands and the resultant oiliness of the skin heightens the ill effects of such substances as tar and petroleum, while excessive dryness may form an obstacle to work where the dust and water are alkaline, as in the plains of some Western states.

Eczema.

The great variations in susceptibility to the action of irritants, together with the fact that there are many irritants, makes it difficult sometimes to determine the cause of inflammation of the skin. When the cause is not discovered, the inflammation persists and becomes chronic. The term eczema was formerly applied to inflammations of this type. The term embraced any scaly or wet inflammation of the skin of which the cause was unknown. Since eczema did not respond readily to local treatment—and indeed it could not so long as the irritant continued to act on the skin—it was often looked upon as a constitutional disturbance. This view had some basis, for the resistance of the skin is influenced by the general health; the disease often diminishes as a

result of improvement in the living conditions. More often it improves when the occupation is changed and contact with the irritant eliminated. Practically all of the so-called eczemas are now considered as arising from external causes. The use of the term eczema implies an ignorance of the causative agent which, in many cases, can be discovered only after prolonged search.

Plant Dermatitis.

Many instances of acute and chronic dermatitis arise from contact with certain plants. The irritant principle is in the juice or resin. In some plants the material is so irritating that the mere touching of the leaves or stems is followed by severe inflammation in most persons. Poison ivy and sumac are typical of this type, while the Chinese primrose is similar but less active. Dermatitis has been known to follow the handling of articles varnished with the juice of the Japanese lacquer tree, even when the varnish has been applied several hundred years before. In many other plants the irritant material is relatively weak, and only an occasional person is affected. The working of certain woods causes a dermatitis in susceptible persons. The rash developing from teak is the most common.

In most of the plants which produce a dermatitis the irritant agent is an oil. A little time is required for this oil to penetrate the skin after it is applied, so that it is often possible to destroy or remove the irritant before any serious effects can develop. Washing the area of contact with soap, preferably strong laundry soap, immediately after touching the plant, will often prevent poisoning. Washing with alcohol or gasoline may have the desired effect.

Occupational Dermatitis.

Every occupation brings the worker in contact with irritants of the skin as both physical and chemical agents. Although the causes of dermatitis are thus almost universal, dermatitis only develops when an irritant is encountered in such strength or with such persistence that it overcomes the resistance of the skin. For example, almost everyone is exposed to sunlight and, for the most part, without injurious effects. Nevertheless, exposure to intense sunlight produces sunburn, which is a typical acute dermatitis.

Similarly, many persons use soap and water upon their skin without untoward effects, but for the washwoman and scrubwoman these substances may excite dermatitis.

Chemical Agents.

Occupational dermatitis is prevalent among domestic workers. The chief irritants are soap and hot water. Red and roughened hands from dishwashing and laundry work are the mildest forms of chronic dermatitis. The stronger cleaning materials used by scrubwomen and washwomen are proportionally more irritating. The dermatitis is of sufficient severity to deserve the distinctive name of "washwoman's dermatitis." A similar condition occurs in the hands of barbers, washers of automobiles, and in fact among the workers in any occupation involving the constant use of soap and water.

The salts of certain metals, either in solution or as dust, produce severe inflammation of the skin. Chromic acid and the salts of chromium are particularly noteworthy in this respect. In addition to the ordinary type of irritative dermatitis, salts of chromium may cause a characteristic ulceration, or "chrome sore." Chrome sores may even occur from handling material that has been dyed by a process using chrome. The salts of mercury and arsenic are also very irritating. Lime dust is a common cause of dermatitis. Portland cement has a similar action, although to a less degree. Both of these substances will produce ulcers if applied in sufficient strength. The septum of the nose is particularly vulnerable to irritating dust and may even be perforated by the ulcers which form.

It is a difficult problem to protect the hands against the action of irritating solutions. Theoretically, rubber gloves offer complete protection, but in practice their use has many objections. Waterproof material next to the skin induces heavy sweating, especially during work in hot liquids. The sweat softens and removes the horny layer, and thus renders the skin tender, thin, and more vulnerable to the action of chemicals.

Physical Agents.

Constant pressure against the skin causes it to become thin, while intermittent pressure or friction stimulates the skin to in-

creased growth, providing the pressure is not sufficient to cause ulceration. Callouses result from intermittent pressure upon the skin. A man in starting work with a pick and shovel develops a characteristic series of changes in the skin of his hands. After a few hours of work the skin becomes thin and sore, and looks red and glazed; sometimes it blisters. In the course of a day or two the outer layers peel off. The skin which is then formed is thicker than formerly. Sensibility is diminished in these calloused areas and pressure is no longer felt. The nature of the man's occupation can often be told by the position of the callouses.

A corn originates in the same manner as a callous but usually only on the feet. The chief cause is badly fitting shoes. A corn is distinguished from a callous by the presence of a central ingrowth of the horny layer of the skin. This ingrowth is in the shape of a cone pointing downward. Its growth compresses the underlying layers of the skin, which become thinner, and a cup-shaped cavity is left when the corn is removed. Pain is caused by the pressure of the central ingrowth against the sensitive deeper layers of the skin. A corn occurring between the toes absorbs sweat and appears white and sodden.

Effect of Freezing on the Skin.

Chilling of the skin causes the blood vessels to contract, thus lessening the flow of blood to the area. Severe chilling may close the vessels completely, thus shutting off the circulation. The area thus deprived of its circulation is easily frozen. There is no pain during the freezing and onlookers are more likely to recognize the condition than the individual himself. The frozen part appears shrunken, dull, and waxy. Freezing occurs most often in the extremities and in exposed parts such as the nose and ears. Children and also old people are more susceptible than vigorous adults.

Some days after the freezing the part gradually shrivels, turns black, and is either absorbed or sloughed off. Even when the tissues are not killed, inflammation may result from the stoppage in the circulation. The effect is not felt until the circulation is restored by warmth. The returning blood exudes into the tissues from the vessels, which are now relaxed. Inflammation develops

with the same sequence of events as in any other dermatitis. The circulation should be restored slowly to the chilled part in order to avoid the inflammation which follows a sudden reëstablishment. The part should be immersed in cold water and rubbed gently; if actually frozen it may be rubbed with snow. As the circulation is restored the temperature of the bath is gradually elevated. A chilled or frozen part should never be exposed at once to heat.

The constriction of the blood vessels caused by cold is often exacerbated in the feet by the shrinking of the wet leather of the shoes. The suppression of the circulation by this combination of conditions may lead to gangrene, that is, death, in the toes or even in the entire foot. In such cases amputation is necessary. "Trench feet," as this condition was named during the European War, is not limited to soldiers in trench warfare, but may occur in anyone who is inactive while exposed to wet and cold, and wearing shoes which are not waterproof. The tramp sleeping on the park bench in the early spring or late fall sometimes develops trench feet. Preventive measures consist in wearing loose waterproof covering for the legs and feet and maintaining as much movement as possible.

Effect of Heat on the Skin.

Burns are caused by dry heat from the contact or proximity of a flame or heated solid body. Scalds are caused by moist heat from the action of heated fluids, steam, or other hot vapors. The difference in effect is comparable to the distinction between roasting and boiling. The skin and even the underlying tissues may be destroyed by the heat and the inflammation which results.

Burns are usually classified in three different degrees which express the extent to which the flesh is destroyed. (The surgical classification includes six degrees, the third degree of the simple classification given here having four subdivisions.) In burns of the first degree the destruction of the tissues extends to only a slight depth. There is pain and reddening of the skin and subsequent loss of the superficial layers. Sunburn resembles a burn of the first degree, although sunburn is not due to heat, but to actinic light, and is not strictly a burn. In burns of the second

degree there is, in addition to the reddening seen in first-degree burns, a formation of blisters either immediately or within a few hours. When the blister bursts and the cuticle is removed the corium is left exposed and is red and painful. In burns of the third degree the skin is destroyed and charred to its full depth, and even deeper structures such as fat, bone, and muscle may be burned.

In burns of the first and second degree the full depth of the skin is not destroyed. During healing, therefore, the skin is readily replaced from the undamaged layer and no scar results. Burns of the third degree, however, result in scars. The extent and nature of the scar formation depend upon the depth to which the tissues are destroyed. In severe burns of the third degree it may be necessary to graft skin to complete the healing. The scars which form in these severe burns contract and pull in the sides of the wound. If the area is large, unsightly puckered scars are thus produced, and if the burn is between movable parts deformity may result. Thus if the palm is involved the hand may be pulled into a claw, or if the burn is at the elbow, the forearm may be pulled up and held against the upper arm. Such deformities from contraction of the scar can be prevented by holding the structures extended by means of splints during healing.

Aside from the local wound, burns and scalds have a general effect upon the body in proportion to the area of the surface affected. A burn or scald of the second or third degree covering one-third or more of the surface of the body is invariably fatal. In burns over smaller areas there may be illness and fever. These general effects are presumably due to the absorption into the blood of products from the burnt tissue.

The treatment of burns aims to afford protection to the raw and inflamed surface and to keep it clean. The surface may be covered by pouring over it a thin paste made of water and baking soda, starch, or flour. Vaseline or carbolized vaseline olive or castor oil, white of eggs, lard, or cream may also be used. After the protecting coating has been smeared over the burn a clean cloth soaked in the material is applied and held in place by a light bandage. Picric acid is a good dressing for

burns and is applied in the form of gauze impregnated with the acid. The strip of picric acid gauze is moistened preferably by holding it in steam, and is then applied over the burnt area. This compress is held in place with a bandage. Picric acid increases the pain slightly at first, but lessens it later.

In severe and extensive burns the mortality is high and death often occurs during the first hour or two from the shock and pain. Such cases should, if possible, be taken at once to a hospital. If delay cannot be avoided they are best treated by immersion in a tub of water to which salt is added at the rate of approximately an ounce per gallon of water. The bath is kept at a temperature of 95° to 100° F. The immersion can be made with the clothes on.

Infectious Dermatitis.

Physical and chemical agents are not the only causes of dermatitis; bacteria which attack the surface layers of the skin likewise produce dermatitis; and these types of dermatitis are communicable.

Impetegio contagiosa is a common infectious dermatitis. It is caused by a form of streptococcus. This bacterium resembles the cocci normal to the skin, but its form of reproduction is different and it is much more virulent. The disease commonly appears on the face and commences as a red spot which rapidly becomes a vesicle, or even a blister, and then a pustule. The pustule dries into a yellowish crust, which appears loosely attached to the skin.

Impetegio contagiosa spreads rapidly from person to person by contact. A whole room in a factory may be thus infected. The disease is common in schools, where it may assume epidemic proportions, especially among those engaged in athletics necessitating close contact, such as wrestling and football. The disease sometimes goes by the name of football itch. It is not to be confused with ringworm, which is a fungous growth on the skin also common among those engaged in athletics, and which generally occurs in the groin, toes, or scalp. If left to itself, impetegio contagiosa will go on indefinitely, reinoculating itself on different parts of the body. Mild cases of impetegio can readily be cured by a few applications of an ointment of ammoniated

mercury. When the infection is extensive, treatment by a dermatologist is required.

Seborrhea, or Dandruff.

Seborrhea, or dandruff, is primarily a dermatitis of the scalp. The skin of this region is thick and resistant to irritation. Dermatitis there differs from that seen on the thinner skin of the rest of the body. There is usually no redness, and only a slight itching. The dermatitis is of the scaly type and the scales which are shed are known as dandruff. The disease is not, as popularly supposed and as the name seborrhea implies, a perversion in the flow of grease from the sebaceous glands. It is believed that the irritation that causes the seborrheic dermatitis is due to bacteria, probably to a specific bacterium. But the organism has never been definitely isolated. Nevertheless, there is sufficient evidence in favor of the bacterial origin of the disease to consider it as an infectious condition.

Seborrhea of the scalp affects all ages and both sexes, but males more frequently than females. The scaly crusts which frequently appear upon the heads of infants are due to seborrhea. The chief effect of seborrhea is the gradual thinning of the hair. Baldness is generally due to this disease. In slight cases of seborrhea daily washing of the scalp brings marked improvement. Seborrhea would be much less common were it not for the tradition that washing the scalp furthers the disease. It is almost incredible how long some otherwise cleanly persons are willing to go without washing their scalps. Washing the scalp is not only harmless, but definitely beneficial, providing all of the soap is thoroughly rinsed out. Oils and pomades are harmful.

Acne.

Inflammations of the deeper layers of the epithelium and of the corium, unlike those of the surface layers of the epithelium, are almost entirely of bacterial origin. One of the commonest inflammations of the deeper layers of the epithelium is acne. The essential characteristic of this disease is an excessive formation of the horny cells of the skin at the outlet of the grease glands. This excessive growth leads to the formation of a

comedo, or blackhead. The word comedo is from the Latin, meaning "I eat up," for it was formerly supposed that this growth was a species of worm. The comedo is a small oval body composed of concentric layers of horny cells. The comedo blocks the outlet of the sebaceous gland and the long coil of yellow material, which can be expressed from the gland after it, is retained secretion and not part of the comedo. The black tip of the comedo is not dirt, as is commonly supposed, but is the characteristic color of overdeveloped horny cells. The same pigmentation appears in the scales in severe ichthyosis and in the skin in elephantiasis.

Most comedones remain without seriously disturbing the sebaceous glands which they block. In some cases, however, the distended gland becomes infected and filled with pus. The pustule thus formed has the comedo at its apex. In some instances the infection is deep and extensive and a boil is formed. Sometimes the connective tissue of the corium thickens about the infected areas and the consequent irregularities in the surface of the skin cause considerable disfigurement.

Ordinarily, acne is a disease of adolescence; it means literally "the bloom of youth." After thirty it is rare except in persons taking bromides or iodides, or in those in contact with tar or oil during their works, when it is called "oil acne."

The form of acne common in youth is difficult to eradicate. There is, however, one infallible cure, and that is time; for when the sufferer becomes twenty-five or thirty years of age, the condition passes off. Much improvement can be effected earlier by proper treatment. The comedones should be gently removed with an instrument sold for this purpose, and one which does not bruise the skin. The skin over the affected areas should be washed frequently with soap and hot water. Greasy applications are to be avoided, as is also facial massage. The general health should be cared for by proper food, fresh air, exercise, and sufficient sleep. In severe cases of acne a dermatologist may render valuable service by treatment that can be given only under medical supervision. The proprietary ointments and salve sold for the treatment of acne frequently do more harm than good,

although they all effect a "cure" if used until the age when the disease naturally disappears.

Oil Acne.

Infections of the skin, and particularly acne, often follow the repeated wetting of the skin with oil. There are two ways in which these infections are produced. One is simply the inoculation of scratches with pus-forming bacteria. Oil which is used over and over again as a lubricant in metal cutting in a machine shop becomes highly contaminated with bacteria. Scratches are often caused by tiny particles of metal. Such particles are carried in the oil and lodge between the fingers, or are caught in rags and waste and cut the hands as they are wiped. This type of infection is readily overcome by filtering the oil each time it is pumped through the machine and by sterilizing it daily with heat. The addition of disinfectants to accomplish the sterilization is not satisfactory, for the disinfectants themselves are irritants and may cause dermatitis.

A second type of infection from oil occurs in the grease glands and usually appears as acne or boils. The acne is produced primarily by the stimulating action of the oil upon the growth of the epithelial cells; typical comedones and acne pustules appear. The boils result from the infection of the hair follicles and grease glands with bacteria carried in the oil. Certain oils, particularly those from coal tar, have the property of stimulating the skin to excessive growth; they may also cause warts and in some instances even cancers.

Leprosy.

Leprosy is caused by a bacillus which closely resembles that of tuberculosis. The bacillus of leprosy produces lumps or tubercles similar to the nodules in tuberculosis. The lesion of leprosy, however, is limited to the skin, mucous membrane of the nose and mouth and the nerves. The first symptoms usually appear as changes in the skin. Sharply defined areas become reddened and finally pigmented. Occasionally the pigmentation disappears and a white area is left. This blanching is rare in leprosy, but probably from Biblical description is associated in the popular mind as

a regular and characteristic sign of the disease. Consequently, the comparatively common disease leucoderma often gives rise to the suspicion of leprosy.

Leprosy is a very ancient disease, but under the Hebrew term used in the Bible and translated as leprosy there are embraced apparently many skin diseases other than leprosy. The disease was prevalent throughout Europe during the fourteenth and fifteenth centuries. During the sixteenth century a marked decline occurred as a result of segregation, and today the disease persists in only a few areas. The number of persons afflicted with leprosy in the United States is uncertain. In 1902 a government commission took a census of lepers and reported 278. Of this number 73 cases were in isolation and 205 were at large. The official figures for a census in 1912 are 146. The census of 1910 in India reported 110,000 cases of leprosy. The disease is prevalent in China. In 1914 there were 3,439 lepers in isolation in the Philippine Islands. Leprosy was introduced into the Hawaiian Islands about 1859. The conditions there were favorable for propagation of the disease, it spread rapidly among the natives, and nearly 3 per cent became leprous. Strenuous efforts have been made to stamp it out in the Hawaiian Islands by segregating the lepers on the Island of Molokai.

Few diseases inspire such dread in the minds of most people as does leprosy; but in reality it is difficult to transmit leprosy. The direct inoculation of the bacilli into condemned criminals has in only one instance led to the development of the disease, and in that one instance the man came from a leprous family. The bacilli are present in the open sores, and in the sputum and nasal secretion when the mucous membrance of the nose and throat is involved. The disease is unquestionably communicated directly from the sick to the well, but except in rare cases prolonged and intimate contact seems necessary for the transmission. Leprosy does not spread among those who are clean. Very few nurses and doctors in attendance at leper colonies have contracted the disease. Crowding and the conditions of poverty promote its spread. As soon as a country becomes economically able to adopt the tidiness of modern civilized life, leprosy dies out. The children of lepers are not born with the disease.

Leprosy has a remarkably long period of incubation; the disease is not usually recognized until at least seven years have elapsed after exposure, and this time may extend to twenty years. The course of the disease after it is recognized is also long; cases of thirty years' duration or even longer are not unusual.

Anthrax.

Anthrax is primarily a disease of herbivorous animals, particularly sheep, goats, and cattle. The infective agent is the anthrax bacillus. This organism has the property of forming spores. The anthrax bacillus itself is readily killed, but the spores are very resistant and may remain for many months clinging to hides, wool, or hair, by which they are transmitted to man. When brought into a suitable environment these spores develop into anthrax bacilli.

Man may be infected with anthrax in the intestines, lungs, or skin. The intestinal form results from eating the meat or drinking the milk of infected animals, and occasionally from bacteria carried to the mouth from an infected area on the man's skin. The symptoms of intestinal anthrax are those of cholera; the mortality is high. Pulmonary anthrax is called "wool-sorters' disease" or "rag-pickers' disease" from the prevalence of the infection among men engaged in these occupations. The bacteria are carried into the respiratory passages in the dust from infected materials. Like the intestinal form, the disease is acute and generally fatal.

Anthrax of the skin occurs chiefly among those engaged in handling hides, wool, or hair. It has been known, however, to follow the wearing of a coat lined with sheepskin. A recent epidemic was traced to the hair in shaving brushes. Infection of the skin starts as an itching red spot quite like the bite of an insect. The infection spreads rapidly and within a few hours a reddish-black area appears, about which the skin is swollen and inflamed. In severe cases the bacteria are disseminated throughout the body.

An anti-anthrax serum is now available for treating the disease. Prevention of the disease consists in disinfecting the hides, hair, and wool, particularly those imported from Mongolia, Persia,

Russia, and India. There is very little anthrax among the animals of this country; it is extremely important to prevent its occurrence through the contamination of the land or water. For this purpose the refuse from tanneries and woolen mills should be sterilized before it is used as fertilizer.

CHAPTER XIII

PARASITES AND THE DISEASES THEY CARRY

A VARIETY of insects prey upon man as their source of food. These parasites attack the skin and their bite produces irritation and inflammation. The itching induces scratching, which carries into the wound any infectious material on the skin adjacent to the bite or upon the fingers. These local effects are, however, less important than the infectious diseases which may be transmitted by these parasites. Insects form an essential step in the transfer of the germs of such diseases as malaria, yellow fever, bubonic plague, and the African sleeping sickness.

Lice.

Pediculi, or lice, are flat, elongated, wingless insects with stout legs ending in sharp claws. In front is a short beak or proboscis through which extends a slender stylet used to puncture the skin. In feeding, blood is sucked through the proboscis. Three species of the louse prey upon man: Pediculus capitis, or the head louse; Pediculus corporis, or the body or clothes louse; and Pediculus pubis, or the crab louse.

Head Lice.

The head louse, as its name implies, limits its activities to the scalp and more particularly the rear portion of the scalp. The eggs are firmly cemented to the hairs and can readily be seen as white specks known as nits. The bite of the head louse gives rise to crusted sores on the scalp. In severe cases the hair becomes tangled in these crusts and matted together, forming a firm mass, or "plica polonica," so named because of its relatively frequent occurrence among the Jews of Poland. The lymph glands at the back of the neck swell from the drainage of the infected areas. Head lice are commonest among people of unclean habits, but children of the better classes often become infected from playmates or nurses. Bathing the scalp with kerosene oil or tincture

of larkspur kills the parasites. The nits can be removed with a fine comb.

Body Lice.

The Pediculus corporis, or body louse (the cootie of the late war), lives in the clothing, particularly the seams, and goes to the body only for food. The bite causes minute hemorrhagic spots which itch intensely. The bodies of those infested show linear abrasions on the skin about the neck, back, and abdomen, made by scratching. In chronic cases these scratch marks become permanently pigmented and characterize the condition known as vagabond's disease. The prevention of body lice is almost entirely a matter of personal cleanliness. Anyone may become infected with lice by contact in crowds or trains, or indirectly through beds in hotels and sleeping cars. No one should be blamed for having lice, but only for keeping them.

Crab Lice.

The crab louse is found in the parts of the body covered with hairs, such as the pubes, and more rarely the axillæ and eyebrows. It is transmitted through contact, or indirectly from unsanitary water closets or privies. Itching is the most marked symptom. The insects are easily eradicated by a few applications of mercurial ointment.

Typhus Fever.

The body louse, and occasionally the head louse, are transmitting agents for the germ of typhus fever. This is an entirely different disease from typhoid. It prevails in epidemic form only in overcrowded and filthy surroundings, and is sometimes called jail fever, camp fever, or ship fever, for unsanitary conditions in such places cause it to assume epidemic form. The crowding, dirt, and other unhygienic conditions in lands devastated by war and among the refugees lead to the spread of typhus, as in Serbia in 1915. The disease is sudden in its onset; a skin rash and high fever develop, but usually terminate about the end of the second week. The death rate varies in different epidemics from 12 to 20 per cent. Since body lice live in the clothing, it must be disinfected to remove the parasites. Dry cleaning in gasoline or

heating the clothing are effective methods. Bathing with an antiseptic soap serves to remove any stray lice from the body. These procedures were carried out in the great delousing stations in Serbia during the war.

Bedbugs.

The common bedbug, Cimex lectularius, does not live in as close association with the body as does the louse. Nevertheless, this insect has become a thoroughly domesticated animal in all parts of the world. The bedbug lives in the crevices of wooden bedsteads and in cracks in the floor and walls. It is nocturnal in its habits. It feeds by puncturing the skin and sucking blood; it may live for very long periods without feeding.

The occasional presence of bedbugs in a house is not necessarily an indication of neglect or carelessness, but, like lice, their retention is. The insect is usually introduced upon the clothing of visitors or servants, or in the baggage of travelers; it may come back in the clean clothes from the laundress. The bedbug is suspected of assisting in the transfer of several communicable diseases, but the case is not proved.

Fleas.

Fleas are wingless, blood-sucking parasites which can both crawl and leap. Their ability in this last respect has been greatly exaggerated in the popular mind. Fleas can jump to a height of three to five inches, seldom over six inches, a point of considerable practical importance in preventing infection from the ground. Fleas cannot cling to the smooth surface of rubber boots; and, since they cannot jump over six inches, they cannot reach the top. There are many species of fleas; the more common are known by the names of the animals which they ordinarily infest; the dog flea, or Ctenocephalus canis; the cat flea, Ctenocephalus felis; the common rat flea, Ceratophyllus fasciatus; the squirrel flea, Ceratophyllus acutus; and the common flea, Pulex irritans. Although fleas as a rule prefer certain hosts, they are not as particular in this regard as many parasites. The common species mentioned above will attack several hosts, including man. This democratic tendency on the part of fleas makes them par-

ticularly dangerous parasites, for they are the bearers to man of a disease of rats, the bubonic fever, or plague.

The female flea deposits her eggs among the hair or fur of the host; but these eggs are not fastened to the hair, as in the case of the louse, and therefore fall to the ground, usually at the animal's sleeping place. The eggs hatch in the rubbish, and in cracks and corners; the larval fleas feed on nearly any kind of organic refuse. The adult blood-sucking parasite develops from the larval state and jumps to a host upon which it feeds and lays its eggs.

Bubonic Plague.

The flea is the transporting agent of the germ of bubonic plague. Although not primarily a skin disease, plague is usually transmitted to man through the skin, and so is dealt with here. This disease is primarily a disease of rats and secondarily of man. The flea affords the necessary transmitting agent both from rat to rat and from rat to man. Bubonic plague is the famous "Black Death" which swept through Europe in the fourteenth century and destroyed about a quarter of the population. During the eighteenth and nineteenth centuries the disease became less prevalent and there were only minor outbreaks, chiefly in Asia. In 1894 an outbreak took place in Hong-Kong and spread as far as Europe and the United States. From 1896 to 1911 there were seven and a half million deaths from plague in India.

The disease is caused by the pest bacillus and appears in two main forms—the common or bubonic form and the less common pneumonic plague. In the first type the lymph glands swell and usually fill with pus. Such swollen and suppurating glands are known as buboes, from which the disease derives its name. This characteristic involvement of the lymph glands is accompanied by fever and other symptoms of severe infection. Small dark red spots appear on the skin. When the plague ravaged Europe these small areas of hemorrhage into the skin were called "plague spots" or "token of the disease," and gave the name "Black Death." The mortality may be as high as 80 or even 90 per cent.

The pneumonic type of plague is a primary infection of the

lungs with the pest bacillus. This form of the disease is nearly always fatal, death occurring in from two to four days. Pneumonic plague differs markedly in one respect from the bubonic type, which is not contagious from person to person except through the agency of the flea, for the reason that the bacilli are not present in the sputum or nasal secretion. In the pneumonic type of plague, on the contrary, the bacilli are present in these secretions and the disease is spread by contact directly from person to person without the agency of the flea. One attack of the plague usually protects against a second. A fair degree of artificial immunity may be obtained by the use of anti-plague serum or by plague vaccine (Hoffkin's prophylactic). The effects of the serum lasts only about three weeks, and that of the vaccine only six months.

Prevention of Bubonic Plague.

Although other insects can be controlled, the eradication of the flea is an impossible task, and the eradication of the rat, except in limited localities, appears to be almost equally hopeless. The number of rats in cities and upon farms is tremendous; it is estimated that there are some twenty or thirty million rats on the Island of Manhattan alone. The damage to food by rats is enormous; it costs at least a dollar a year to support each rat. To this direct damage must be added the injury to buildings and their contents, for rats not only destroy materials to build nests and to make passageways, but gnaw indiscriminately to wear down their rapidly growing incisor teeth. Consequently rats will attack lead water pipe, and the lead coating of electric cables, and even plaster. These economic losses are secondary to the great menace of the plague. Owing to the difficulty of eradicating rats, the efforts of the United States quarantine to prevent the introduction of plague are largely confined to protecting the local rats from acquiring the disease through the immigration of rats with the plague. Fortunately, fumigation kills rats with certainty in any inclosed space. In ships coming from parts of the world where there is plague, the rats on board are killed by fumigation. Sulphur dioxide and hydrocyanic acid gas are the main agents used for this purpose. These agents have the advantage of also

killing the fleas with which the rats are infested. The ground squirrels of California were at one time widely infected with plague. Except for the quarantine and public health service plague would ravage our cities.

Rats breed with such enormous rapidity that anything short of complete extermination is of only temporary effect. It has been shown that the number of rats is dependent upon their food supply. If their access to food is restricted they eat each other and so limit their own numbers. The moral of this is evident. Rat-proofing of places where food is stored is the one essential and effective measure.

Mosquitoes.

The mosquito is a blood-sucking parasite. It only infests man temporarily in order to feed. Because it is not an habitual parasite it is unfortunately not regarded with the odium attached to the louse, flea, or bedbug. Nevertheless, of these four the mosquito is the most deadly insect. It transmits malaria, yellow fever, and the less common tropical diseases, dengue and filariasis. The loss of life and the total of ill health and diminished vigor resulting from the first two of these diseases far exceed the ravages of the more spectacular typhus or plague for which the louse and flea are responsible.

Male mosquitoes are vegetarians, but to the females of most of the species blood is indispensable for the formation of the eggs. All but the adult stage of the development of the mosquito are aquatic. The eggs are laid in water and hatch into larvæ, or "wigglers." Although these larvæ are aquatic, they breathe air through a small tube which they project at intervals above the surface. After about a week the larvæ pass into the pupa stage, from which the adult mosquito emerges a day or two later. The stagnant water of pools, ponds, ditches, and marshes forms the natural breeding place of mosquitoes. Even small and temporary deposits of rain water left in hollows or footprints may serve. No body of water is too small for a mosquito hatchery and nursery. Mosquitoes will breed in the water held in cisterns, cesspools, rain-water barrels, fire buckets, sagging gutters of houses, broken bottles, tin cans, and the hollows in trees,

Mosquitoes can be kept out of houses by screening, but a much more satisfactory method of control is the complete eradication of these insects. Although mosquitoes may be carried to considerable distances by the wind, they do not fly more than half a mile from their breeding place. Thus the eradication of all breeding places within a comparatively small radius from a house or town rids it of all except the mosquitoes blown in by the wind. The most satisfactory method of destroying the natural breeding places is by drainage and filling. When such radical methods are not practicable the next resort is oiling. A film of oil upon the water prevents the larvæ from breathing and thus suffocates them. Sufficient oil is applied to cover the entire surface with a thin film. The oil must be renewed at frequent intervals. In addition to the control of the natural breeding places all artificial pools of water such as cisterns, tin cans, and the like must be either emptied or screened.

Malarial Fever.

Malaria is one of the most widely prevalent of all infectious diseases, and few infections compare with it in the total number of fatalities. In distribution malaria extends from the arctic circle to the equator, but is most severe in warm climates. Malaria is a preventable disease and has been practically stamped out in some countries. In the last half century it has greatly diminished in the United States; it is now rare in the northeastern part of this country, but it still exists in many regions of the South, although with much less than its former prevalence. The fevers common in the tropics are largely malaria. In 1908 there were more than three million deaths from fever in the Punjab. Malaria is the greatest obstacle to settlement by the white man along the rivers and coasts of tropical countries.

Malaria fever is caused by a microscopic animal parasite or plasmodium. This parasite lives and breeds primarily in one variety of mosquito, the Anopheles. It is transmitted to man by the bite of the mosquito; it uses him as an intermediary host or stepping stone to reach other mosquitoes, which in turn are infected by biting the man. So far as known the plasmodium does not impair the health of the mosquito.

The symptoms of malaria arise largely from the disintegration of the red blood corpuscles caused by the parasite. The attack commences with a chill. In severe cases the sufferer shivers so violently that the teeth chatter and the whole body shakes. The chill lasts from a few minutes to an hour or even longer. Although the skin is cold, the temperature of the body rises rapidly during the chill and may go as high as 104°F. Following the chill, the blood vessels of the surface relax and the skin becomes hot, red, and dry, although the temperature of the body does not usually increase beyond the temperature attained during the chill. This hot stage is often accompanied by a violent headache and intense thirst. In a half hour to three or four hours perspiration appears and the headache and acute discomfort passes off for some hours or days.

The paroxysms of malaria occur at intervals which depend upon the time required for the cycle of development of the parasite in the red corpuscles. In one type, tertian fever, this segmentation occurs every three days; in another type, quartian fever, the paroxysm occurs every fourth day and is usually milder than the tertian type. Double or even triple infection may occur, so that parasites may appear in the blood each day, and with a daily paroxysm. There is a third type of malaria in which the symptoms are irregular and in which the fever may be either intermittent or continuous. In temperate climates malaria is not often fatal, but in tropical countries severe forms of the disease occur and the death rate runs high. These severe fevers are usually of the irregular or continuous type. The destruction of the red corpuscles may be so extensive that the urine is colored with hemoglobin or its products, giving rise to the name "black-water fever."

Quinine is a drug which kills the malaria plasmodium within the blood. It is an alkaloid derived from the bark of the chinchona tree, a native of South America. Large doses cause an unpleasant ringing in the ears, while blindness occasionally results from its excessive use. Some persons are particularly susceptible to the drug. Quinine is not readily soluble, and when it is compressed into the form of pills, it often passes through the diges-

tive tract without being absorbed. For this reason quinine should always be taken in solution, as a powder or in capsules.

Prevention of Malaria.

The prevention of malaria is best effected through the eradication of the Anopheles mosquito. It must be remembered, however, that the malaria plasmodium can be transmitted to mosquitoes only from a man infected with the disease. Therefore it is essential that all cases of the disease be isolated in inclosures made tight from mosquitoes by netting so that they will not be infected. Where mosquito eradication cannot be practiced, as in traveling, or camping, or while engaged in carrying out the more permanent type of eradication, quinine prophylaxis is used. Small doses of the drug, two or more grains, are taken daily and the constant presence of the quinine in the blood prevents the development of the parasite. In 1902 the Italian government began the sale of quinine at low prices to communities which distributed it free of cost to those unable to purchase it. In 1904 the towns gave it to all working people. In consequence there has been a progressive reduction in the amount of malaria in Italy. The deaths from malaria during the ten years previous to 1902 averaged 14,048 annually, whereas in the nine years following 1902 the average fell to 3,853. The plan has been equally successful in tropical countries. No ill effects have been noted from the prolonged use of quinine as a prophylactic.

As malaria is lessened by the prophylactic use of quinine, prosperity increases owing to improvement in strength and energy of the people. The increasing prosperity leads to better hygienic conditions, to an interest in anti-mosquito measures, and thus to an eradication of the disease.

Yellow Fever.

Yellow fever is an acute disease in which the skin is often tinged yellow by bile, the characteristic from which the disease derives its name. Yellow fever is a much more acute disease than malaria; in various epidemics the mortality has ranged from 15 to 85 per cent. Like malaria, yellow fever is transmitted by a mosquito—the Stegomyia calopus. This mosquito is not so widely

distributed as the Anopheles or malarial mosquito. Ordinarily yellow fever is a disease of tropical and subtropical countries; its active range is from 38° south to 38° north latitude. Temporarily, but only in the summer time, the disease may extend beyond these limits, and epidemics have occurred as far north as Boston.

The organism which produces yellow fever, like the malarial parasite, does not appear in the secretions of the body, so that the disease cannot be transmitted by contact, but only by inoculation. Furthermore, the active agent can be obtained from the blood only during the first three days of the disease. A period of twelve days elapses between the time the mosquito has ingested the blood and the time that it can transmit the disease. The mosquito may live for a considerable time thereafter and inoculate many persons.

The control of yellow fever depends upon the isolation of the cases from mosquitoes to prevent the infection of the insects, and upon the eradication of the mosquitoes. The anti-mosquito measures against the Stegomyia calopus are essentially the same as those employed against the Anopheles, but with one difference: The Anopheles breeds largely in marshes, swamps, and woodlands, and is not primarily a domestic mosquito. The Stegomyia is thoroughly domestic. Its range of flight is very limited. It breeds about houses, in cisterns, tin cans, sagging roof gutters, rain barrels, water pitchers, or in any small deposit of water. The measures of eradication, therefore, depend upon the screening or removal of every collection of water about the house, rather than the drainage and oiling of swamps and pools in the countryside. The city of Havana, which for 130 years had been continuously infested with yellow fever, was cleared of the yellow fever mosquito in 1901. Quinine is not a prophylactic against yellow fever.

The coast of South America is badly infested. For centuries the Isthmus of Panama was known as the "white man's grave." The building of the Panama Canal through the Isthmus was a sanitary quite as much as an engineering achievement. The rusted dredging machinery of former attempts still stood in the swamps where it had been left by the men killed by the mosquito.

Dr. Gorgas and his staff, appointed by the United States for this purpose, eradicated the mosquitoes and thus made possible the construction of the canal.

Scabies, or Itch.

Scabies, or "the itch," is a distressing skin eruption caused by a minute insect or more correctly a mite, the Acarus scabiei, or itch mite. The insect is just visible to the naked eye. The female excavates oblique tunnels in the horny layer of the skin and lays her eggs as she advances. Small blisters are produced at first and these usually become infected and filled with pus. The infected areas itch intensely and this itching is particularly troublesome at night. The insect chooses the more delicate portions of the skin in which to burrow, and particularly between the fingers and toes, on the back of the hands, in the axillæ and on the front of the abdomen.

Scabies is usually contracted by sleeping in an infected bed, although it is possible to contract the disease by shaking hands. Usually scabies is easily cured. The patient takes a hot bath and then anoints himself with sulphur ointment. The anointing is repeated five times at intervals of twelve hours, after which he bathes and puts on fresh clothes. The application of the sulphur ointment should not be continued beyond five or six applications, for the sulphur may itself irritate the skin.

Hydrophobia.

The wounds caused by the bites of dogs, cats, and other animals are essentially like ordinary lacerated wounds and are easily contaminated. Such wounds usually heal without complication if they are carefully cleaned and dressed. But there is a special danger from the bite of animals in the possibility that the virus of hydrophobia or rabies may be inoculated. Hydrophobia is a disease to which all warm-blooded animals are susceptible. The virus is present in the saliva and is transmitted only by inoculation. This inoculation is usually effected by the bite of the animal, but may occur from entrance of the saliva into a scratch in the skin. Thus rabies occasionally results from merely handling the diseased animals or being licked by them. The disease is

usually transmitted to man by the dog; less commonly by the cat, wolf, skunk, and other animals. There is no authentic case of the transmission of the disease by man, although this may be possible. The number of cases in men is not very great; but unless treated, it is always fatal. Between 1909 and 1921 there were 806 deaths from rabies in the United States. It is not known how many cases were prevented by proper treatment during this period, but the exposure must have been considerable, for 22,000 patients applied for the Pasteur treatment in 1923.

The length of time elapsing between the inoculation and the development of the disease ranges for man from two weeks to three months. This incubation period is shorter in children than in adults. Rabies develops more rapidly from wounds about the face than from wounds in the extremities. Rabies is a disease of the nervous system; the virus travels along the nerves to the spinal cord and brain and not through the blood. The acute stage of the disease usually commences with a change in the disposition and emotions. The man becomes irritable and melancholy. Gradually a stage of excitement comes on. Any stimulation, such as a sound or even a draft of air upon the skin, causes a violent spasm of the muscles, particularly about the mouth and larynx. Any attempt to drink water is followed by a spasm of the larynx; and as it is extremely painful, the sufferer dreads the sight of water, hence the name hydrophobia. The stage of excitement and spasm lasts for two or three days and passes into a stage of paralysis. Spasms no longer occur, unconsciousness develops, and death follows usually within a day. Sometimes the stage of excitement does not appear and the disease is marked from the beginning by paralysis—the so-called dumb rabies.

Contrary to general belief, rabies does not occur exclusively in hot weather; temperature has no influence upon the disease and the fact that cases are particularly prevalent during warm weather is due to the circumstance that dogs roam more freely then.

Rabies can be eradicated. In England a strict enforcement of the law requiring the muzzling of dogs, and a quarantine on all imported animals, kept that country entirely free from the

disease from 1903 to 1918. At the latter date a dog, which was smuggled in again introduced the disease. By 1921 this recrudescence had been successfully terminated. The eradication in England was accomplished simply by legal regulation, but since that time an additional preventive measure has become possible. Prophylactic treatment may now be given to dogs rendering them immune to rabies. In 1924 approximately two-thirds of the dogs in Tokyo, Japan, numbering altogether some 90,000, were treated with the vaccine. Prior to that date there were 1,700 cases of rabies per annum among the dogs; after the inoculation the figure was reduced to 41 cases.

A bite by an animal should always be treated immediately and by a surgeon if possible. The treatment consists of opening the wound and promoting free bleeding. Every part of the wound should be cauterized with fuming nitric acid. The animal inflicting the bite should be captured alive if possible, and kept in captivity. If the animal dies within the next week, preventive inoculation should be administered to the person bitten no matter how thorough the cauterization has been. If the animal survives, there is reasonable assurance that it was not suffering from rabies. If the animal was shot instead of being captured alive, the head should be sent to the state laboratory for diagnosis as to rabies. If the animal escapes, and there is any suspicion of rabies, a prophylactic treatment is advisable. Once established, rabies is hopelessly incurable; therefore no precaution should be omitted in its prophylaxis.

The preventive inoculation for rabies was developed by Pasteur in 1883. When the virus obtained from a mad dog is injected into a rabbit the disease occurs in the rabbit after an incubation period of fourteen to twenty-one days. The virus is then taken from the spinal cord of the rabbit and transmitted through a series of rabbits. In this transmission the virus is altered. It becomes much more virulent for rabbits so that the disease develops on the sixth or seventh day, and death follows on the ninth or tenth. But at the same time the virulence for man decreases. When the virus has been raised to its point of highest virulence for rabbits, the infected animals are killed and their spinal cords removed. This nervous tissue contains the modified virus in

abundance. It is dried and ground into glycerine or other preservative agents. The injection of increasing doses of the vaccine thus produced renders the human recipient immune to rabies. The immunity appears two weeks after the treatment and lasts at least two years. The degree of the immunity varies to some extent; for a small percentage of persons die of rabies in spite of the treatment. In 1908 one died out of a total of 524 treated at the Pasteur Institute in Paris.

Pseudohydrophobia is a neurotic or hysterical manifestation which may occur in nervous persons who are bitten by dogs. These persons have a marked dread of rabies and imagine they have contracted the disease. The symptoms appear at any time from a few hours to many months, and may show some resemblance to rabies. Usually the symptoms are absurdly exaggerated; for example, the man may bark like a dog and attempt to bite his attendants. Unlike true rabies, this purely imaginary disease can be cured.

Snake Bites.

All of the poisonous snakes of North America, with one exception, belong to the class of vipers. The exception is the "coral snake" found in the Southern states. The vipers are characterized by erectile fangs. The jawbone to which the fangs are attached is jointed in such a manner that it rotates when the snake strikes, thus causing the fangs to project straight forward. These fangs have a central canal and are pointed at the end like a hypodermic needle. Poison is forced through them by a muscle which contracts upon the poison gland at their base. The poisonous vipers include the rattlesnakes, of which there are more than a dozen species, the copperheaded adder, and the water moccasin. In the poisonous snakes belonging to the class of *elapidæ,* the fangs do not project forward when the snake strikes. To this class belong the coral snake of North America, the cobras, and numerous other snakes of India and of Australia.

The flesh in the region of the snake bite is seriously damaged by the venom, particularly by that of vipers. These wounds resist feebly and are readily infected with bacteria. They suppurate and the flesh about them dies; they heal poorly, and only

after a long time. The wounds made by venomous snakes must be treated immediately if the treatment is to be of any benefit. A tourniquet is first placed on the limb above the wound; this can be made from a handkerchief, necktie, belt, or any other strip of fabric, and twisted with a stick, pistol barrel, or any convenient object. Next the wound is opened with a knife, so that the full depth of the point of the fang is exposed. The wound even may be cut out completely. Permanganate crystals rubbed into the open wound destroy the snake venom. In the absence of permanganate crystals, which should be included in all first-aid supplies in countries infested with snakes, the wound may be cauterized with a hot iron or burning wood. After the local treatment has been applied the tourniquet is loosened for a few seconds and tightened again. The tourniquet should never remain in place more than ten minutes without being loosened for a short period to allow some circulation to the isolated part, otherwise the limb may be killed. Alcohol is not a cure for snake bites, as popularly believed, and it is best not to administer it.

Antitoxins are now available which counteract the systemic action of the venom of the various classes of snakes. To be of benefit the injection must be made very soon after the bite. If given properly, these antitoxins are effective. After the danger of constitutional effects has passed the wound made by the snake and by the emergency treatment should be carefully bandaged and kept scrupulously clean, for serious local infection often follows, particularly in tropical countries.

Stinging Insects.

There are numerous insects which puncture the skin and inject irritant and poisonous substances. These insects use their sting as a weapon of defense and are not blood-sucking. Scorpions, spiders, centipedes, bees, wasps, and hornets are the most common of these stinging insects.

The poison of the scorpion is secreted in glands in the last segment of the abdomen; the shell of this segment is pointed and forms the sting through which the poison is discharged. The poison of the scorpion is said to be more potent than that of a cobra. It is secreted in relatively small amounts, however, so

that, contrary to common belief, fatal poisoning by the scorpion is rare in adults, although the sting of the larger variety may be fatal in children. The local effects of the sting of the scorpion are severe. There is intense pain and inflammation about the wound. The flesh often dies in the inflamed area and readily becomes infected, and serious results are generally due to this local infection. The sting of a scorpion should receive the same local treatment as a snake bite.

The poison apparatus of the spider consists of two long pouches lying in the thorax and extending into the jaws from which the poison is discharged. Some of the larger spiders, or tarantulas, found in Russia, Italy, and tropical countries, cause severe poisoning. The poison resembles snake venom, but the quantity injected is small. Man is rarely killed by the bite of a spider. The bite of the larger spiders should be treated like snake bites.

The centipede has large poison glands which discharge at the apices of a pair of specialized claws that take the place of the first pair of legs. The nature of the poison is unknown. The effects of the bite are mainly local. The inflammation, however, may spread some distance along the surface and cause severe pain. Severe poisoning in adults may cause nausea and vomiting; rare fatalities occur in young children.

CHAPTER XIV

THE NERVOUS SYSTEM, ITS SERVICE AND FAILURES

Integrative Action of the Nervous System.

The activities of all parts of the body are so controlled that the whole of the system is applied to one objective at a time. Instead of each organ or limb acting independently of the others, all of the organs, especially the muscles, are so specifically stimulated that each plays its part toward the particular activity. It is through this integration that purposeful action is possible. The integration is effected by means of the nervous system consisting of the nerves, the spinal cord, and the brain.

The nerves run to and from the spinal cord and brain, thus connecting all parts of the body with the nervous centers; they form the system of communication within the body. In this respect they are analogous to the wires of a telephone system, for which the brain and cord are the central switchboard. Impulses travel to the brain in sensory or afferent nerves. Impulses travel from the brain in motor or efferent nerves.

Afferent impulses are aroused by stimulation at the far end of the nerve. The stimulus which arouses the impulse may come from within the body and result from the activity of one of its parts; or it may be due to some force outside of the body acting through one of the organs of sense, such as that of sight, by which it is transformed into a nervous impulse.

When an afferent impulse reaches the cord or brain it is retransmitted. It is to effect this retransmission that the cord and brain serve as a switchboard. The efferent impulse then follows outward along the pathway into which it is switched in the cord or brain. So long as a certain incoming path and outgoing path are connected the impulses coming in by the one go out by the other without interference from other incoming impulses. Certain incoming and outgoing nerves are thus connected for the moment as exclusively as are two subscribers of a telephone system after the operators have made their connection.

Although the brain and cord function as the switchboard, it is a switchboard with no operator; the incoming path brings about its own connection for the outgoing messages, much as in the new automatic telephone switchboards. This whole process of stimulation and response is termed a reflex. Some reflexes are simple in the connections made for the retransmission of the impulse; others are exceedingly complicated, as in complex and apparently voluntary acts. The pathways and central connections for some of the reflexes are established before birth; others develop soon after and are the same in all individuals. These intrinsic or "unconditioned" reflexes are involved in such wholly automatic and unconscious acts as the secretion of saliva when food is put into the mouth. The pathways and central connections for other reflexes, acquired or "conditioned" reflexes, are developed through experience and may therefore be different in different individuals. This type of reflex involves consciousness in its development, although later it may become nearly instinctive. The secretion of saliva as the result of hearing the dinner bell is a reflex of this type. The reactions made by a man to his surroundings and toward other men, which appear to himself to be voluntary, are largely determined by his acquired reflexes.

Impulses sent through motor or efferent nerves determine the activities of structures such as muscles and glands to which they are connected. This part of the mechanism is relatively simple; the variety of acts in which any one muscle may participate is due to the complexity of the switchboard and the almost infinite connections and combinations of connections made by the cord and brain for the relaying of impulses.

Impulses coming into the higher centers in the brain give rise to a modification of consciousness known as perception. Thus when a man puts his hand on a hot stove an intrinsic reflex immediately withdraws his hand, for the incoming impulse has been retransmitted to the muscles of his arm. At the same time he perceives that he has burnt himself and that he has moved his arm. Similarly the eyelids wink involuntarily when the eye is touched. Consciousness of the fact that the hand has been burnt or the eye touched is not necessary for the accomplishment

of the act. Unless the nervous system were profoundly injured or depressed his hand would jerk away and his eyelids would wink, even if he did not will to do so and were indeed unconscious of the act. This is seen best when a frog, whose brain and all consciousness have been destroyed but its spinal cord left intact, wipes a drop of acid off its leg. The connections for this intrinsic reflex are made in the cord; if the cord is destroyed the reflex no longer occurs.

The Nervous System and Human Behavior.

The working of the nervous system is illustrated in every act. For example, a man sees an object on the ground. The impulses transmitted through sensory nerves from the eyes to the brain give rise to this perception. The man's subsequent behavior, his reaction to the particular circumstances, is then determined by the sum of his intrinsic and acquired reflexes. If the object is for him neither desirable nor dangerous, he ignores it. If it is offensive he avoids it. If it is desirable he picks it up. Which of the three reactions he will make seems to him to depend upon the ideas which the sight of the object induces in his brain. But in reality animals which have practically no ideas, such as butterflies, go toward objects that stimulate them attractively, and avoid objects that stimulate them repulsively. In such reactions consciousness is a sort of artifact and the man merely rationalizes his own almost automatic behavior. His nervous system being what it is, he could not have acted otherwise.

The perception of the object on the ground sets in train a series of responses on the part of the man. Impulses are sent to certain muscles of the body and they become active. At the same time the muscles opposing the active muscles remain relaxed, so that they do not oppose the activity. The man leans over and extends his arm toward the object. While the act is being carried out, impulses travel up sensory nerves bearing information as to the extent of the movement of the muscles and of the shape, texture, and temperature of the object touched. At the same time sensory nerves from the organ of equilibrium, the canals of the inner ear, bring to the brain subconscious information as to the position of the body. These impulses originate

others, which automatically make the needed connections in the brain and spinal cord, so that impulses go out through motor nerves to muscles not directly engaged in the act of picking up the object. These muscles move various parts of the body in such a manner as to compensate for the movements of other parts in the opposite direction, so that balance is maintained. The integration of activities extends farther and includes the function of the internal organs; breathing and the circulation are both altered during the movement of the body. If the movement is vigorous or prolonged, both of these functions are augmented.

An act apparently as simple as stooping to pick up an object is in reality enormously complex. It is only through the integrative activity of the nervous system that it can be accomplished. The accurate working of this integration is in part inherent in the very structure of the central nervous system, which affords, therefore, certain patterns of response identical in all men, because they are characteristic of the structure of man; animals of other species may have some other response to the same stimuli. In part certain patterns of response are developed by experience and particularly by education. A man does not play the piano except after developing the necessary pattern of successive momentary, nervous connections. We speak of voluntary acts, but most of a man's acts have been repeated until they are nearly as automatic as those which are inherent and instinctive.

Exclusion of Interfering Activity.

In the performance of an act the exclusion of interfering activity is nearly as important as the activation of the structures concerned in carrying out the act. This exclusion is an essential part of the integration effected by the nervous system. It consists in shutting out extraneous and opposing or detracting afferent impulses, as well as in the prevention of simultaneous activity by antagonizing muscles. When the biceps muscle contracts and pulls up the forearm, the triceps muscle remains relaxed so that it will not interfere with the movement. In the wagging of a dog's tail or the scratching with his foot, in a man's walking as he swings now one leg and now the other, the activation and relaxation are alternated so that a reciprocating form of move-

ment results. The movements of breathing are accomplished by this same type of alternation.

A diminution of activity in the cerebral centers such as those involved in perception, similar in effect to the exclusion of interfering activity in the motor system, is manifest as sleep. Very little is known of the physiology of sleep. A diminution in the rate of the circulation through the brain has been observed to accompany it. A decrease in the cerebral blood flow induced by a hot bath or the taking of food tends to promote sleep. A considerable fall in the arterial pressure leads to an unconsciousness like sleep, in syncope or fainting. In most persons the time for sleep is a matter of habit; but no amount of practice can reduce the time for sleep below the minimum required for health. This minimum is, however, quite different in different individuals; the young and aged need more sleep than the vigorous adult. Certain mental factors also have their influence in inducing sleep. Monotony is one of these factors; a sound repeated at very short intervals and a boring lecture both promote sleep. In animals, and probably in man, a failure to complete the sequence of stimuli habitually followed by a certain pattern of response induces sleep. Thus a dog which has been regularly summoned to its meals by a dinner bell falls asleep if the feeding is delayed after he has heard the bell. The time spent before the meal at a dinner party while awaiting the arrival of a late guest is notable for its depressing effect.

Structure of the Nervous System.

The unit of the nervous system is the nerve cell, or neurone. Each neurone consists of a cell body, like that of other cells, but with one or more hair-like processes or fibers extending away from it. Some nerve fibers attain a length of three feet or more. When many nerve fibers extending from one section of the body run in a bundle, like the wires of a telephone cable, and are surrounded by a sheath of connective tissue, the structure is then called a nerve. The sciatic nerve which runs down the leg and which is as thick as the little finger, contains thousands of nerve fibers; some are motor, some are sensory, and some are the so-called sympathetic fibers which control the size of the blood

vessels. The tip of each nerve fiber is connected with the structure to which or from which it carries impulses, a muscle fiber or a sensory organ.

Besides the main nerve fibers, or axones, many shorter processes may extend like rootlets from the body of the neurone. These are called dendrites. The connections for the transmission of impulses between neurones are made by contact between the nerve fiber of one neurone and the dendrites of the next, or through the dendrites of two or more neurones; the points where the dendrites

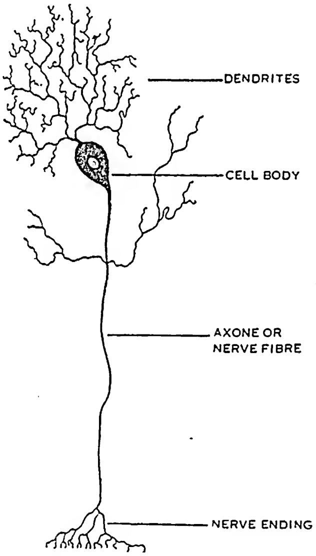


Figure 37. NEURONE.

thus interlace and connect are known as synapses. Several afferent nerve fibers may have synapses with the dendrites of many efferent cells, so that an impulse arising from any part of the body may be transmitted to several structures simultaneously, and may cause their coöperative action in a definite pattern of response elicited only by that particular stimulus. Such connections between neurones occur only in the so-called gray matter of the spinal cord and brain, where the nerve cells also lie. This is the switchboard; for the synapses afford the apparatus by means of which, in the language of the telephone, one incoming line is connected now to one set and now to another set of outgoing

lines. The afferent line is connected not merely to a single outgoing line, but to a set of efferent lines suitable to effect the particular response appropriate to the particular stimulus. The nerves which ramify throughout the body, with the exception only of the sympathetic nerves, do not communicate after they have left the spinal cord.

The Spinal Cord.

The spinal cord is a collection of nerve fibers and nerve cells, and extends through the canal within the vertebræ. It is about

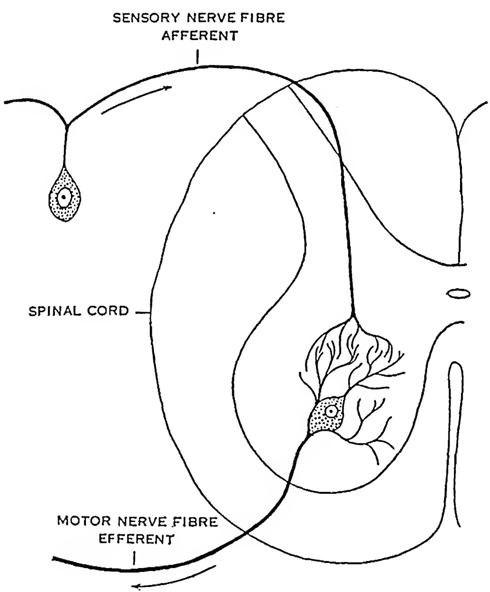


Figure 38. Schema of Cross Section of Spinal Cord.
Showing connection between the neurone of the dorsal root (sensory) and the neurone of the ventral root (motor)—the reflex arc.

eighteen inches long. The brain and spinal cord are known together as the central nervous system. Nearly all of the sensory nerves except those from the sense organs of the head enter the spinal cord. Likewise the motor nerves to all the muscles of the arms, legs, and body lead from the spinal cord. The afferent nerve fibers entering the cord make synapses both with the dendrites of these motor neurones and with other neurones which extend upward to the brain.

The sensory nerve fibers enter at the back of the spinal cord, the dorsal or posterior roots of the cord. The cell bodies of these neurones are located outside of the cord in enlargements, or ganglia, upon the nerves. After entering the cord these fibers, in most instances, continue their course in the posterior part of the cord up toward the brain. At intervals they give off processes which make connections with the processes from other nerve cells. Motor nerve fibers leave the cord near the front, the ventral or anterior roots of the cord; unlike the sensory nerves, their cell

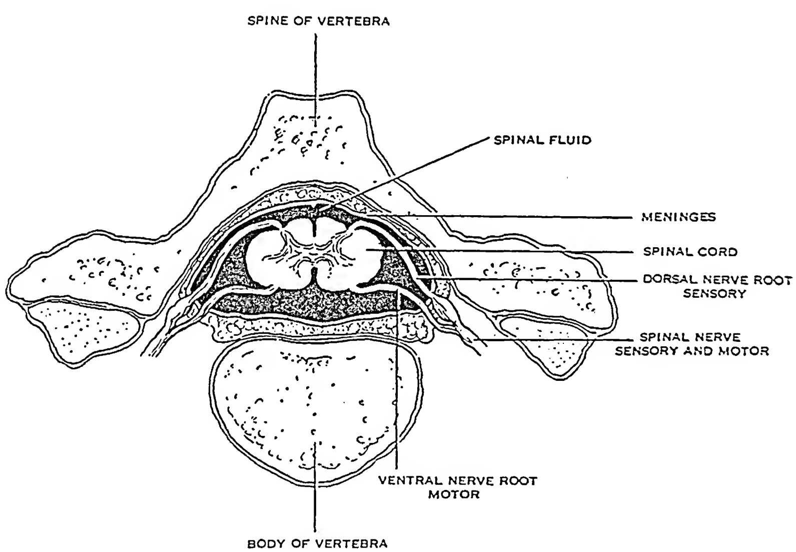


Figure 39. CROSS SECTION OF VERTEBRA AND CORD.
Showing the formation of the spinal nerves from the dorsal and ventral roots.

bodies are within the cord. Dendrites extending from their cell bodies make connections both with sensory neurones and with nerve fibers from cells in the gray matter of the brain. Thus two groups of intraspinal fibers make connections one with the motor and the other with sensory neurones and thus serve to relay nerve impulses up and down. In some instances the connection between the motor and sensory fibers in the cord is direct; but more often the connection is through one or more relays. In case the stimulus induces a very complicated "voluntary" response, such as the writing of a sentence, the relays carry the impulses up to the brain, where the switching of the impulses is

correspondingly complicated, and the resultant impulses are finally sent down again and out through motor nerves.

The nerve fibers enter or emerge from each side of the spinal cord in groups, the spinal roots, which pass between the vertebræ. A short distance from the cord the spinal roots from each side unite and are inclosed by a common sheath to form nerve trunks. These spinal nerves then run to all parts of the body and supply the sensory and motor fibers for all the "receptor" and "effector" organs of the body.

The Gray Matter.

The substance of the cord and also of the brain is made up largely of nerve fibers which run from one part of the brain to another, or to the cord, and form the pathways of communication. The fibers constitute what is known as the white matter. In addition to these fibers there are within the substance of the cord and brain, and particularly in the centers of the cord and upon the surface of the brain, masses of nerve cells and dendrites through which the connections are established between fibers for reflexes. These nerve cells and their dendrites make up the gray matter of the brain and cord. Certain of these masses have special control over the functions of particular organs. They are often called nerve centers. Thus there is a respiratory center which is concerned in the control of respiration.

The Spinal Bulb, or Medulla.

The spinal cord on entering the skull continues its course for a few inches and is known, in this locality, as the brain stem. This stem divides above into two divergent arms which extend into the mass of the cerebrum. The first portion of the brain stem, the spinal bulb, or medulla oblongata, resembles the cord except that it is of somewhat greater diameter and complexity of structure. In it are located the centers controlling breathing and also the centers which control the tonicity of the blood vessels, the rate of the heartbeat, and so on. All the nerves emerge from the spinal cord or its short extension within the skull. The nerves which come from the extension of the cord after it has entered the skull are known as cranial nerves. The two vagus nerves which arise

from the medulla are of this type. After emerging from the skull they extend down the neck and into the chest and abdomen, sending fibers to many of the visceral organs. The vagus nerve has been mentioned previously in its (efferent) function of controlling the rate at which the heart beats, and in the (afferent) regulation of breathing; it also influences the motility and secretions of the alimentary tract. The medulla, while functioning chiefly below the level of consciousness, thought, and voluntary motions, nevertheless controls the basic, or "vegetative," functions of the body, those functions in which all vertebrates are

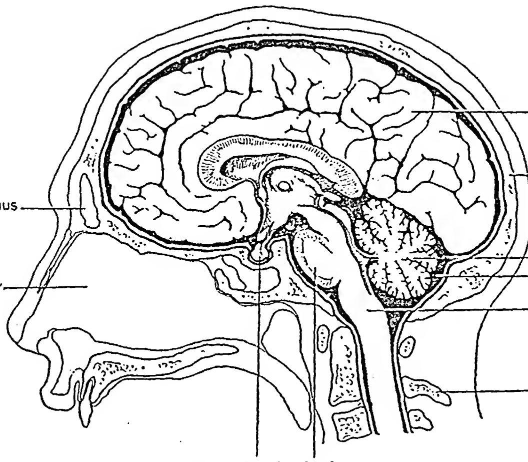


Figure 40. Sagittal Section of the Brain.

essentially alike. Damage to the medulla leads to death through cessation of breathing; fortunately, it is well protected from external injury by its situation at the base of the skull.

The Cerebellum.

Directly above the medulla the brain stem bulges still further to include a band of nerve fibers extending laterally across it. This band of fibers is called the "pons," or bridge, and connects the two sides of a mass of nerve tissue, white matter within and gray matter on the surface, known collectively as the cerebellum. The cerebellum is approximately the size of the clenched fist; it is located back of the medulla. The function of the cerebellum is imperfectly understood; but it is known to play an important

part in the coördination of muscular movements. While the more conscious movements are regulated by the cerebrum, the cerebellum influences the less conscious movements of locomotion and plays an important part in the finer muscular adjustments, such adjustments as are made by the skilled operators of the arts and trades. These functions are seriously interfered with as a result of damage to the cerebellum.

The Cerebrum.

The extension of the brain stem above the pons and cerebellum is known as the mid-brain. In it are located centers for motor

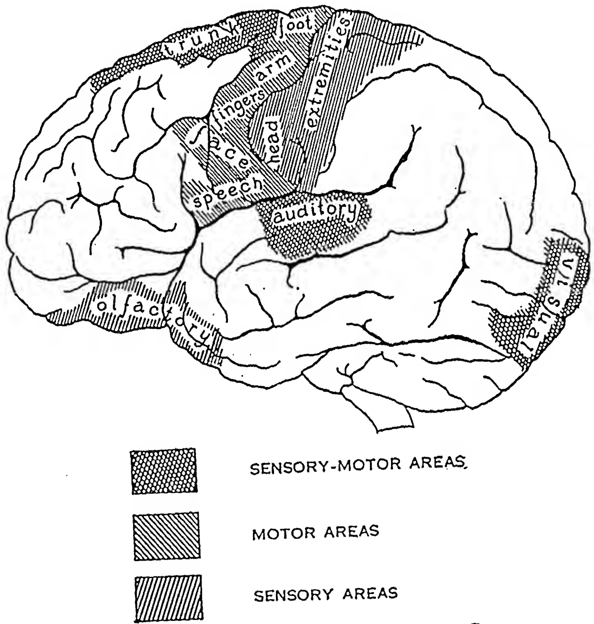


Figure 41. Cerebrum from Lfet Side.
With functional area of cortex indicated.

and sensory nerves from the eyes and ears. The remainder of the brain, and in man by far the largest part, is known as the cerebrum. In it take place the associations of impressions that constitute thinking, memory, imagination, and the process of willing acts. The voluntary motor areas and paths are especially highly developed in the human brain. If the cerebrum of a dog is removed it may still continue to live, to move about, and avoid

obstacles by means of sight, but its intelligence is gone. A man in whom the cerebrum is extensively damaged by disease cannot reason, remember, or perform any voluntary act.

The cerebrum fills the cavity of the skull above the level of the eyes. Its surface is convoluted so that ridges are formed with fissures between them. The location of the main fissures is constant in all human brains, and in the study of the brain they serve as marks for defining its areas. The activities controlled by some of the centers on the surface of the cerebrum have been determined. The motor areas have been defined particularly well; they cover a vertical strip about midway on each side of the brain. The pathways down from these areas cross, so that the area on one side of the brain controls the muscles on the other side of the body (see Figure 41).

Pathway of Motor and Sensory Nerves.

From the motor areas of the cortex of the cerebrum nerve fibers extend into the spinal cord (see Figure 42). There they form junctions with other nerve cells which send fibers to the muscles. Impulses sent out along this line of relays produce the complex voluntary acts. Most of the motor fibers extending down from the cerebrum cross, as mentioned above, to the opposite side of the cord at about the level of the medulla. Consequently, the muscles on each side of the body are largely controlled from the motor areas on the opposite side of the brain. For this reason injury to these areas on one side of the brain is followed by paralysis of the muscles on the opposite side of the body.

The path followed by the sensory impulses in passing up to the brain is more complicated than that from the brain down to the motor nerves. The neurones whose nerve fibers connect with the sense organs of the body have their cells in the dorsal roots of the cord, or in the case of the special senses in the continuation of the cord within the skull. From these cells the fibers continue up the cord and like those of the motor nerves but higher up, cross to the opposite side of the brain stem and then pass to the cerebrum. Other and more complex paths make connections with the cerebellum and other parts of the brain.

The Meninges and Cerebrospinal Fluid.

Both the cord and the brain are loosely covered with membranes which collectively are known as the meninges. Inflammation of these membranes, arising from bacterial infection, is called meningitis. The space between the membrane and the brain or cord is filled with a fluid which resembles lymph. This cerebrospinal

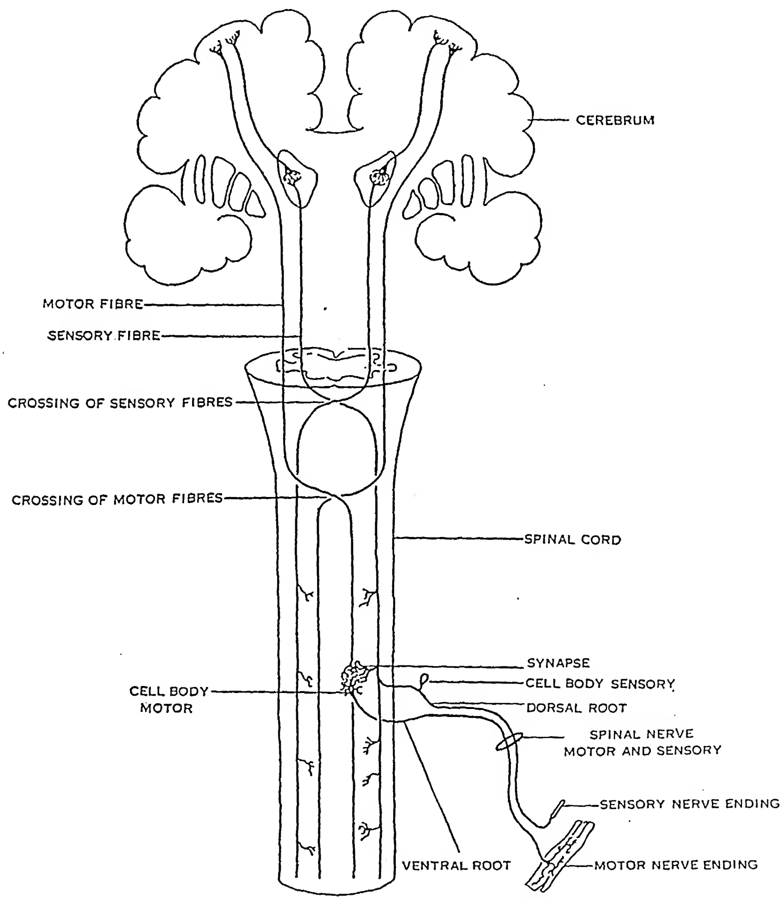


Figure 42. Pathways of Motor and Sensory Nerve Fibers.

fluid is derived from the blood; its pressure normally is that of the venous blood leaving the brain. Within the substance of the brain are cavities filled with this same fluid, which are in communication through narrow passages with the fluid beneath the meninges. If for any reason these passages are shut off, as they

may be by a tumor of the brain or by tubercular infection of the brain, the fluid accumulates within the brain and its pressure rises: the process is analogous to that of glaucoma (see Chapter XVI). As a result of the pressure thus developed the nervous tissue is compressed; in children in whom the bones are still growing the skull is forced out of shape and becomes in some instances much enlarged, the condition of hydrocephalus.

The pressure of the fluid about the brain may also be increased by alteration in the size of the brain, due to an increase in its content of water. Severe asphyxia by carbon monoxide may cause such an absorption of water. Intense headache results—all headache is not, however, of this origin. By injection of strong salt solution into the blood water may be withdrawn from the brain, and the headache and other symptoms of brain pressure, arising from the asphyxia caused by carbon monoxide, may be relieved.

Diseases of the Motor Nervous System.

Disease or injury in the nervous system usually manifests itself not at the point directly affected, but rather as alterations in the action of the organ to which the nerves from this area of the brain are connected. The relation is analogous to that in a telephone system; a break in a telephone line, or a crossed wire in the central station, manifests itself in a useless telephone far from the real defect. In a like manner a clot of blood pressing upon nerve fibers in the brain results in paralysis of one side of the body; but no headache or other symptoms occur in the area of real damage.

When the motor areas of the brain or the nerves leading from them are injured, the action of the muscles is affected. This interference may appear either as overaction or as paralysis. Overaction is designated, according to its intensity and nature, as tremor, spasm, or convulsion. Tremor is a rapid to-and-fro movement of antagonistic muscles. In an otherwise normal person it may be occasioned by fatigue, or by the toxic action of excess coffee, tobacco, or alcohol, or by more serious poisons such as lead and mercury. A convulsion consists of involuntary and purposeless, that is uncoördinated muscular contractions. When it is limited to a small group of muscles it is spoken of as a

spasm. The rapid twitching of the eyelid which many persons experience as a result of eye strain or fatigue is a spasm.

Tic.

A type of muscular movement know as a "tic" resembles a spasm, but is distinct from it in that the tic is not caused by any irritation or derangement of the nerves. A tic is a habit spasm; a movement occasioned at first from some local cause such as rubbing a sore spot on the face, or from the imitation of some one else, and repeated until it has become habitual. The movements involved in the tic are those of any voluntary act, but the motions are usually exaggerated. The act may be that of repeated winking, drawing up the eyebrow or cheek of one side of the face into a grimace, licking the lips, nodding, sniffling, coughing, scratching, or tapping some part of the body.

Convulsions involving large groups of muscles sometimes occur in children; they may be due to digestive disturbances, the beginning of an infection, or to irritation of some organ such as the bladder. Usually they pass off and have no after effects; they are merely an expression of the lack of stability of the immature nervous system, like the instability later noted in the nerve centers regulating the temperature of the body. If the convulsions occur repeatedly it is probably epilepsy.

Epilepsy.

Epilepsy arises from a disturbance in the cerebral centers. It is characterized by brief loss of consciousness with convulsive movements of the muscles; such attacks are called "grand mal." Less often there is transient loss of consciousness without convulsions, and such attacks are known as "petit mal." The cause of most cases of epilepsy is not known. In cases of so-called Jacksonian epilepsy, the convulsions are due to pressure upon the cerebrum either from a fragment of bone displaced through injury to the skull, or to growths such as tumors or cysts within the brain. Jacksonian epilepsy can sometimes be cured by surgical operation; but for success the operation must be performed soon after the first appearance of the attacks. The ordinary types of epilepsy are not benefited by operation.

In grand mal the convulsive attack is preceded in many cases by what is known as an "aura," a brief warning of the impending fit. The "aura" may consist of an emotional state amounting in some cases to insanity with hallucinations, or it may consist of dizziness, flashes of light, or some coördinated muscular movement such as running or whirling about. At the onset of the fit a loud cry or groan may be given. The man then falls to the ground unconscious; the muscles throughout the body contract intermittently with a jerking movement. Saliva exudes from the mouth and may be stained with blood if the tongue is bitten by the snapping of the jaws. The fit usually lasts for two or three minutes, after which the man is sleepy and depressed. Occasionally during the bewildered state after the fit, he may perform unconsciously acts which appear to be purposeful; he may start on a journey, or may take part in a conversation of which he has no recollection afterward.

In petit mal the motor centers in the cerebrum are not involved; only the higher or psychic centers. The attack consists of unconsciousness without the convulsions which characterize grand mal. The unconsciousness is usually very brief. The man will suddenly stop whatever he is doing, drop anything he has in his hands, and stand still for a few seconds. After the attack the man may perform some automatic action such as walking for a short distance in a bewildered manner.

Attacks of epilepsy may occur at any time in those afflicted, even during sleep; they often occur in public places. In such circumstances the bystander can afford only slight assistance; he can merely prevent the epileptic from injuring himself during the convulsive movements, or he may insert a piece of wood or a rolled handkerchief between the epileptic's teeth to prevent him from biting his tongue. Other first-aid treatment is useless. After the fit is over the man should be removed to a quiet place where, after he recovers, he may be spared the embarrassment caused by the gaping crowd whose curiosity leads them to stop and watch the epileptic have his fit.

Epileptics, either with "grand mal" or with "petit mal" are dangerous as employees when placed in positions where uncon-

sciousness will result in injury either to themselves or others. An epileptic should not be given a position which involves work on scaffoldings, about moving machinery, or electrical wiring, nor where molten metal is handled. He should never be allowed to drive an automobile.

Paralysis.

Inflammation or other injury to the motor nerves or centers may result in partial or complete loss of motion in the muscles which they supply; this is known as paralysis. When the injury is in a nerve after it has left the spinal cord, only the muscles to which that nerve is distributed are involved. When the damage is in the brain or cord many nerves may be affected, and the paralysis is correspondingly extensive; all the muscles on one side of the body may be affected.

Injury to the brain causing paralysis may result from cerebral hemorrhage; this is called apoplexy. The damage may also result from the shutting off of the blood supply to a part of the cerebrum by a plug in a blood vessel, an embolus, or from constriction of the vessels due to arteriosclerosis. Cerebral hemorrhage occasionally occurs at birth; from infancy until the age of about forty the liability is small, but after forty it increases progressively. The predisposing cause to cerebral hemorrhage is arteriosclerosis and the high arterial pressure of advancing years.

At the time of the cerebral hemorrhage the man usually loses consciousness and falls. In some cases the unconsciousness passes off in a few hours. As a rule one side of the body is paralyzed, the side opposite to that in which the hemorrhage has occurred in the brain. If the hemorrhage is on the left side the power of speech may be lost. A few weeks after the "shock" improvement commences, speech may be recovered in some measure, and the paralysis may gradually decrease. The first attack of apoplexy is usually followed by other attacks at varying intervals. The probability of complete recovery becomes less with each attack. In, or after one of these attacks, death occurs.

Inflammation of the spinal cord is knows as myelitis. When the gray matter of the cord containing the cell bodies of the nerves is affected, the term poliomyelitis is used. If the cell bodies of only

the sensory nerves are affected, the condition is called posterior poliomyelitis, because of the position of the sensory nerve roots; a similar involvement of the motor nerves is called anterior poliomyelitis. Posterior poliomyelitis is due usually to syphilis in the spinal cord and is often called locomotor ataxia (see page 321).

The most common type of anterior poliomyelitis results from the acute infection known as infantile paralysis. Inflammation of the cell bodies is much more serious than inflammation of the nerves alone, for when the latter are destroyed the cell body can grow new fibers. When the cell body is destroyed regeneration is impossible and there is then no recovery from the sensory changes in locomotor ataxia or the paralyzed and withered muscles of infantile paralysis.

Injury to the nerves frequently occurs in wounds. The cutting of a nerve leads to the paralysis or loss of sensation in the area which it supplies. The nerve degenerates. If the ends are spliced together soon after the injury new fibers will grow from the cell bodies in the spinal cord or ganglia, and these fibers follow the course of the degenerated nerve and replace it. Sensation is then restored and it is possible to use the muscles again. If the ends of the nerve are not spliced together the replacement extends only to the stump of the central end of the nerve and the paralysis is permanent.

Neuritis.

Inflammation of the nerves is known as neuritis. If the inflammation is mild the function of the nerve is interfered with and in the case of sensory nerves there is pain. Paralysis follows severe inflammation of the motor nerves. The mildest form of inflammation results from pressure upon the nerve; a tingling sensation is felt in the part supplied by the nerve and the muscles are moved with difficulty; the affected part is then popularly said to be "asleep." If the pressure has been prolonged, as, for example, from sleeping in a chair with the arm thrown over the back of the chair and the head resting on the shoulder, the paralysis may last for months.

Serious inflammation of motor nerves sometimes occurs as a result of diphtheria or from poisons, of which lead and alcohol

are the outstanding examples. In lead poisoning the muscles which support the wrist are paralyzed, giving rise to the characteristic "wrist drop." The paralysis of alcoholic neuritis is usually in the adductor muscles, those holding up the foot, and causes "foot drop."

CHAPTER XV

THE SENSES

It is through the various senses that we obtain knowledge of our surroundings. The sense of touch gives information concerning objects with which the body comes into actual contact. The sense of taste distinguishes certain properties of soluble substances placed in the mouth. The sense of hearing affords information of the vibrations in the surrounding air which we call sound. Hearing, unlike touch and taste, gives information of events occurring at a distance from the body. The sense of sight reaches still further into space; there is perception of light even from a star at a distance of a thousand "light" years. In many animals smell is also a sense which is important in affording information regarding food and enemies at a distance.

Internal Sensation.

Sensations do not all relate to the outside world. They are continually arising from all parts of the body and information is thus given of the activities taking place. Thus we are constantly aware of the position of our bodies, of our hands and feet, and also of the extent of their movements.

Sensations arising from internal organs like the heart, stomach, intestines, and bladder are not ordinarily brought into consciousness, unless intensified by some special cause rendering them painful. One is unaware of the bladder until it becomes distended with fluid; then the demand for evacuation arises and becomes imperative in consciousness. Even though we are largely unconscious of the sensations arising from internal organs, their sum total blends into an indefinite sensation which contributes largely toward our conscious state of feeling or well-being or discomfort. These subconscious nervous impulses play constantly an important, and, indeed, an essential part in regulating the working of all the organs of the body.

How Sensations are Received and Interpreted.

The perception of any sensation depends upon the action of three structures in succession: first the receptive organ upon which the source of energy (light, sound, etc.) acts, initiating the sensation; second, the nerve which leads from the receptive structure to the brain; and third, the particular area of the brain to which this nerve is connected and from which we draw the consciousness of sensation.

Energy in many forms, called stimuli, acts upon the receptive structures and arouses a nervous impulse which is carried in the nerves. The receptive structures are specialized, so that each type responds to only one form of energy: hearing to sound, sight to light, and so on. In the skin there are several distinct senses—heat, cold, touch, pressure, and others, each with its own specialized and selective type of receptive organs. But there is only one kind of nervous impulse for all.

The nervous impulse is transmitted through the nerves, which lead to the spinal cord and to the brain. In this respect the nerves are like wires which are used to conduct electricity; for the nerves, or conductors, are connected individually to separate areas of the brain, just as telephone wires are connected to separate lights at the switchboard, or as bell wires are connected to individual members in an annunciator system. When an impulse comes in on any nerve to its particular brain area, we feel in some definite portion of our skin, or hear, or see, according to the type of receptive sensation which characterizes that particular area of the brain.

We may even construct an artificial system to represent the arrangement of receptor, conductor, and indicator. For this analogy a push button, a selenium cell, a thermopile, and a microphone may serve for the receptors, and would correspond to four senses. These instruments might be connected by wires, representing the nerves, to separate recording mechanisms, such as four galvanometers. When the push button is touched a galvanometer responds; light striking the selenium cell brings a response in a second galvanometer; sound acting upon the microphone and heat upon the thermopile actuate the third and fourth galvanometers. By observing which one of the galvanometers responds, we can infer the type of energy acting upon the receptive apparatus, even

though it is at a distance and out of sight in another room. In the body a similar recognition and interpretation takes place in the brain. It is not, however, consciously referred to the brain, where alone it exists as a modification of consciousness, but is projected outward to the source of stimulation. Thus we refer a sensation of touch to something just outside the skin; taste not to the tongue but to the contents of the mouth; sight not even to the eye, but to the outer world, perhaps to an object across the street or in the sky.

Since there is only one form of nervous impulse, irrespective of the source, it follows that the sensation aroused in the brain is determined solely by the particular nerve affected. A very striking example of this is afforded by the eye. If the nerve leading from the eye to the brain is jarred or otherwise irritated mechanically, impulses are aroused in the nerve and these are perceived as flashes of light. This is the explanation of the "stars" seen from a blow on the eye. The phenomenon can occur in a totally dark room and "light" is thus seen where none exists. A disagreeable experience arising from a like cause is common to those who have lost a leg or arm; they may suffer pain in the missing fingers or toes. This effect arises from the excitation of the severed nerves in the stump, but it is referred by the brain to the positions formerly occupied by the missing members. So, too, extracted teeth may ache and the pain even be referred to the false teeth replacing them.

Still another type of disturbance may occur in the system by which sensation is received and interpreted. From some intrinsic cause the brain may become excited and record sensations which are not occasioned by any impulse arising from external sources of energy. Thus in fever, mental disease, poisoning, or intoxication, there may be visual or auditory hallucinations. The individual apparently "sees" objects or animals which in reality are not before him. Thus are occasioned the "snakes" seen by the acute alcoholic, and the "voices" heard by the insane.

Intensity of Sensation.

In order to arouse a sensation, not only must energy be applied to the receptive organ of the particular sense, but the amount

of energy must exceed a certain lower limit. In relation to sound, for example, the tick of a clock which cannot be heard at thirty feet may be audible at sixteen feet. At the shorter distance the energy of the air waves is sufficient to arouse the sensation of sound; at greater distances the energy is insufficient. The lower limit of energy necessary to arouse any sense is known as its "threshold value." The threshold value for any sense is usually different for different persons. For hearing it ranges all the way from unusual acuity to complete deafness. Furthermore, the threshold value varies greatly with the state of attention. A person engrossed in deep thought may be unconscious of external happenings.

Under conditions of strict attention and for the average normal individual, the threshold value for the different senses has been approximated in terms of energy as follows: For the sensation of pressure $\frac{1}{10,000}$ of an erg; for sound $\frac{1}{10,000,000}$ of an erg; for sensation of sight (green light) $\frac{1}{100,000,000}$ of an erg.

As the amount of energy exciting the senses is increased above the minimal or threshold value, the sensation is increased also. But while the energy may be increased indefinitely the intensity of the sensation never exceeds a certain upper limit or maximum. The application of energy above the maximum produces no increase in the sensation, but causes fatigue and exhaustion of the receptive apparatus. A very brilliant light shining in the eyes results in temporary blindness; and loud sounds are followed by a period of deafness. If the eye is first fatigued by looking at a red object, a white object then for a short time appears green.

Between the threshold and maximal values for any sense, variations in the intensity of the sensation are perceptible. The delicacy with which these changes can be perceived depends, not upon their absolute, but upon their relative amounts. If a one-ounce weight is held in the hand, the addition of a second, a third, or even a fourth ounce is readily appreciated. But the addition of one ounce or even four ounces to an initial load of forty pounds would not be felt. The amount that any stimulus must be in-

creased in order to be perceptible is a nearly uniform percentage for all intensities between the minimum and maximum. Thus, if to a weight of twenty ounces held in the hand, one ounce must be added to cause an appreciable difference, then for a load of forty ounces the same ratio is maintained and two ounces must be added; while to ten pounds a half pound must be added; and so on. This fundamental principle, called Weber's law, applies to all of the senses. We cannot see the stars in the daytime, because the amount of light that they contribute to the illumination of the heavens is too small a percentage of the total to be perceptible. With the setting of the sun the percentage of illumination furnished by the stars is increased, although the stars are themselves no brighter; they then come in to sight in the darkening sky in the order of their brilliancy; faint stars are only seen when there is no moon. The same principle applies to the so-called "glare" of the headlights of an automobile; it may prevent our seeing objects otherwise visible.

Referred Pain.

When pain arises from the skin there is no difficulty in locating its origin. Pain which occurs in the internal organs is not always so readily localized and may be "referred" to parts distant from the actual seat of disturbance. This referring of pain arises from the diffuse distribution of nerves from any one level of the spinal cord. Pain arising from a disturbance of the heart, such as angina pectoris, is frequently felt upon the upper arm and chest wall. An aching tooth in the lower jaw may be felt in the upper. Inability to locate an aching tooth has often resulted in the mistaken extraction of sound teeth.

Pain may arise from disturbance in the nerves themselves, as in "neuritis," or inflammation of the sensory nerves. A mild type of this neuritis, known as neuralgia, gives a dull ache along the course of the nerve which at intervals is varied by a paroxysm of sharp pain. The affliction is most severe in cold and particularly in damp weather. Exposure to cold, chronic infection, arteriosclerosis, and reflex excitation from eye strain or decayed teeth are some of the predisposing factors to neuralgia.

The Skin as a Sense Organ.

The skin, when suitably excited, gives rise to the sensations of temperature, touch, and pressure. The skin itself is not a receptive organ for these sensations; but it is dotted with minute sensory nerve endings, some of which respond to cold, others to heat, others to touch, others to pressure and still others to insults causing pain.

There are on the body some 250,000 minute spots which are receptive to the sensation of cold. Each "cold spot" is connected to its individual nerve fiber going to the spinal cord or brain. There are some 30,000 spots which respond to heat. The skin between these points is insensitive to cold or heat, although if either is applied it is soon felt because of heat conduction through the skin to the nearest sensitive spot.

The terms heat and cold, as they are here used to express opposite conditions, necessitate the assumption of some normal temperature; above this normal is "hot," and the heat spots react and give rise to the sensation of warmth, while the cold spots are not excited. Temperatures below this normal are what we term "cold"; the cold spots are excited, while the hot spots are not. This normal varies with many conditions, so that the sense of temperature is subject to numerous deceptions. Thus the sensation of warmth is caused by immersing the hands in cold water after they have been chilled by exposure to extreme cold, while tepid water feels cold after hot.

The sensations of heat and cold are excited in proportion to the rapidity of change in temperature. We can sit comfortably in a room while the temperature is slowly decreased 5° F. during the period of an hour. On the other hand, on stepping from one room to another 5° cooler or warmer the difference in temperature is at once appreciated.

The strength of the sensation of temperature depends upon the size of the skin area exposed and consequently on the number of receptive organs stimulated. If the whole hand is dipped in water at 98° F. it feels warmer than water at 105° into which only one finger is dipped.

It has been estimated that there are more than half a million points on the skin which respond to stimulation by producing

the sensations of touch and pressure. A person pricked on the skin with the point of a needle can tell with the eyes closed exactly where the needle is applied. This localization results from the fact that each one of the touch and pressure points is connected to the central nervous system by its own nerve fiber. Hence, each elicits a different sensation which is mentally projected to the area of skin excited. If the skin is pricked in two spots very close together, it may be difficult or impossible to differentiate the two points and they are felt as one. The distance that the points must be separated to be felt as two depends primarily upon how thickly the touch and pressure points are scattered over the area examined, upon other factors such as practice, and upon whether the application of the two needles is simultaneous or in succession. An instructive experiment can be performed in this connection by gently pricking the skin with a draftsman's pen and widening the points until two spots are distinguished. In the ordinary individual the tip of the finger will distinguish two points at a separation of about 2 mm., the back of the hand 20 mm., the chest 45 mm. and the middle of the back 60 or 70 mm. The distance is the least where the skin is used for the most delicate touch and where the discernment of slight intervals between objects is most necessary.

Disturbances in Cutaneous Sensation.

Sensation in the skin is influenced not only by diseases of the skin, but also by disorders of the nervous system and other conditions of a general character. When the perception of pain is lost the area so affected is said to be anesthetic. Thus when a nerve trunk is severed in a wound the area of the skin supplied by the nerve is rendered anesthetic. The skin in the anesthetic area may be struck or burned without giving rise to any sensation. Some drugs, such as cocaine and novocaine, interrupt the transmission of nervous impulses. When injected beneath the skin or about a nerve they produce a temporary local loss of sensation. Surgical operations may be performed under this local anesthesia.

In contrast to anesthesia, the skin may be more than normally acute to sensation. When the skin is inflamed, as in sunburn, it is painfully sensitive to touch. When the superficial layers of the epithelium are lost through the bursting of a blister or by abrasion,

the area thus denuded is sensitive, for the nerve ends have lost the protection of the epithelium. The term paresthesia is applied to such perversions of sensation as when one feels that the skin is swarming with insects. Paresthesias are particularly marked in persons addicted to cocaine and some other narcotics.

Itching is a sensation which arises from the irritation of the nerve endings of the skin. It may occur from purely local causes such as the bites of insects. In other cases the irritation may arise from no apparent cause in the area affected; the itching is then spoken of as pruritus. In such cases the nerve endings are stimulated by abnormal or toxic substances brought in the blood. The disease jaundice, in which bile finds its way into the blood, is often associated with pruritus. Similarly, the excessive amounts of sugar in the blood in diabetes may cause pruritus.

Senses of Position and Movement.

Even with the eyes closed we have a definite idea of the position of our limbs. This sense of position is of the greatest importance for controlling movement and especially for the coördination of movement. Through it the individual learns to what extent movements are carried out or fail to be carried out. The nerves which bring to the brain the impulses, which are there interpreted as position, have their origin in the tendons of the muscles, the joints, and to a less degree in the skin.

The interpretation of the sensations of position and movement is derived from experience. The infant is born with these senses undeveloped, and the education is gradual as the nervous system develops. Repeated trial and error lead slowly to the association of the sensations derived from various positions with memory pictures obtained by the senses of sight and touch. The child sees its hand before its face and feels at the same time the sensations associated with this position. Repetition of the act finally results in the ability to assume this position, and to know where the hand is, without requiring the aid of sight. This ability originates in the vaguely groping movements of a young child and leads to the slow development of coördination and skill. To a considerable degree this same education of the sense of position goes on through life as new activities are undertaken. It is developed to

a high degree in those skilled in such sports as tennis and baseball, and in the arts and handicrafts. In fact, "learning a trade" is largely the development of such coördinations.

To a limited extent the sensation of movement can be replaced by sight; when both fail, purposeful movement is no longer possible. This point is well illustrated in the disease known as locomotor ataxia posterior poliomyelitis (see page 311). In this condition the nerves carrying the sensations of position are paralyzed. As the damage begins at the lower end of the cord, the feet and legs are affected first; the sufferer can tell the position of his feet only by looking at them. He walks with a peculiar gait; the legs are thrown wide, raised high, and brought down sharply upon the heel; in the dark he walks with difficulty and stumbles in climbing stairs. Persons afflicted with locomotor ataxia cannot stand upright with the feet together and the eyes closed. A normal person under similar circumstances does not fall, but merely sways slightly, maintaining a fairly good balance by means of his sensations of position.

Senses of Taste and Smell.

By means of the sense of taste we learn the character of solids and fluids taken into the mouth; by the sense of smell the nature of the substances in the atmosphere entering the nasal passages. "Taste," as we commonly think of it, does not arise solely from the mouth, but is largely a matter of olfactory impression. The true sense of taste is capable of recognizing only four characteristics of soluble substances placed in the mouth, namely, sweet, bitter, acid, and salt. All other "taste" impressions, and this includes the flavors that give the delicate distinction to foodstuffs, arise from the sense of smell.

The organs of taste reception in the mouth are located largely on the tongue. The tongue is dotted, particularly at the edges, with minute saccules or goblets, open to the surface through small pores and containing in each a nerve ending. To arouse the sensations of bitter, sweet, acid, or salt, the substance dissolved in water or saliva must enter the pore of the taste goblet and act upon the nerve. Insoluble substances, which are without smell, are "tasteless." When the tongue is coated with mucus, "furred"

as it is called, entrance to the sensitive goblets is partially blocked and the sensation of taste is dulled.

The nerves upon which odors make their impression are in an area about one centimeter (0.4 inches) in diameter in the upper part of the nasal passages. These nerves are exquisitely sensitive to excitation by a great variety of chemical substances. In order that a substance may arouse the sense of smell it must be present as a vapor in the air drawn over the olfactory nerves. It follows that only volatile substances possess odor. So minute is the amount of certain substances necessary to arouse the sense, that for a long time it was believed that the excitation resulted from vibrations from the odorous substances, and that smell was analogous to the sense of hearing. The chief support for this view was that, with such strongly odorous substances as musk, no loss in weight of the material could be determined with the balance. Physical methods more delicate than the balance have demonstrated, however, that these substances do gradually pass into a state of vapor when exposed to the air.

The fact that no appreciable loss in weight was noted can be understood when we consider the extreme sensitivity of the olfactory nerves; thus $\frac{1}{25,000,000}$ of one milligram of allyl mercaptan (the odoriferous principle of the skunk) in one liter of air has a perceptible odor. The sense of smell is not equally sensitive to all substances, for the threshold value varies with the material exciting the sense. The extreme dilution of the mercaptan which can be smelled may be compared with concentrations of other well-known substances as follows: essence of orange $\frac{1}{20,000}$ mg., ether $\frac{1}{2,000}$ mg., and camphor $\frac{1}{200}$ mg. per liter of air.

The continued action of any odor soon results in exhausting the olfactory sense for that particular odor. This is notably true of those who live in close and poorly ventilated dwellings. The individual with an offensive breath is unable to detect it by his own sense of smell.

The nose is in open communication with the throat, and odoriferous substances can pass upward from the back of the mouth

to the olfactory area. This takes place when we eat. While food is being masticated vapors pass into the throat and are carried upward by the air expired through the nose. The movement of swallowing shuts off the communication between the nose and throat, and the sensation of "taste" ceases, except as it is derived from the tongue. Flavored liquids are "tasted" at the completion of swallowing rather than while they are in the mouth. A judge of fine wine, or tea, or other aromatic substance, sips it, draws his breath in over his tongue moistened with the substance, and then exhales through his nose. Thus only are flavors to be fully appreciated. It is a common observation that the sense of taste is blunted when the nasal passages are partially occluded by a severe cold.

Hearing.

By the sense of hearing we become aware of vibrations within a certain range in the surrounding air. The perception of these vibrations we interpret as sound. Sounds are classified under two broad types: noises and musical tones.

Noises are produced by waves which have no regularly repeated movement; their action upon the organ of hearing is in the nature of an irregular series of concussions. Musical tones, on the other hand, are caused by regular periodic aërial waves. The qualities which distinguish musical tones are loudness, pitch, and timbre. Loudness is determined by the amplitude of the sound waves which reach the ear. The greater the distance from the source the fainter the sound, for loudness varies inversely as the square of the distance. The pitch of a tone is determined by the number of vibrations which the sound wave makes per second. The greater the frequency the higher the pitch. The form of the sound wave has no influence upon either the loudness or pitch of a tone, but it does determine that character of sound known as timbre. By variation of timbre we are able to distinguish between different human voices and different musical instruments. A note struck upon a piano is readily distinguished from a note of the same pitch and loudness played upon a flute. The dissimilarity lies in the difference in configuration of the individual sound waves from the two sources. Only a comparatively few

sound waves show a true sine curve when they are reproduced graphically. The proper sound of a tuning fork gives a curve of this type. Most tones are compound, that is, the simple form of the curve is distorted by overtones or partial vibrations. Overtones are produced by independent vibrations arising from segments of the sounding body. These vibrations are superimposed upon the basic sound wave. The variety of overtones in any compound tone establishes its timbre.

The ear is not able to recognize all rates of vibration. Frequencies below and above certain limits are not heard. These limits vary in different persons. The most sensitive ear can perceive vibrations at a rate as low as 15 to 30 per second and as high as 50,000. Sound begins to assume a definite musical character at 40 vibrations per second. The whole range of human hearing is covered in the most favorable cases by 12 octaves; for a rise of one octave the rate of vibration is doubled. In music only about 7 octaves (from 40 to 4,700 vibrations per second) are used. It is probable that some animals—the cat for example—can hear sounds too high pitched to be perceived by the human sense of hearing. The bat flying in the dark avoids obstacles by the echo of a high note which it emits.

Inner Ear.

The mechanical energy of sound waves is very small and the nerve endings which are stimulated by this energy to transmit nervous impulses, must of necessity be extremely sensitive and delicate. Such an apparatus cannot be exposed to the vicissitudes of the body surface; it must be firmly based to prevent jarring, and yet be in sufficient connection with the air to have freely imposed upon it even the most minute movements of the sound waves. All these conditions are fulfilled in the human ear. The true receptive organ is buried deep in the massive bone at the base of the skull. It consists of a canal in the bone, curved and wound into the shape of a snail shell and called the cochlea. The large end, corresponding to the opening of the snail shell, is not covered with bone, but instead is closed with a thin membrane. The canal is filled with fluid and connects with the semicircular canals. The cochlea is lined with the delicate nerve-endings which

receive the energy of sound. Vibrations imparted to the fluid excite the particular nerve-ending corresponding to that frequency, and the sensation of a definite tone is experienced. The fluid in the canal can be set in vibration by sound waves transmitted through the bone of the skull. Thus a sound is "heard" when a vibrating body is held between the teeth or pressed close to any of the bones of the body. Many persons can hear by bone conduction who are deaf to sounds transmitted through the air. Their deafness is due to disarrangement of the accessory apparatus of hearing (described below), which is necessary to trans-

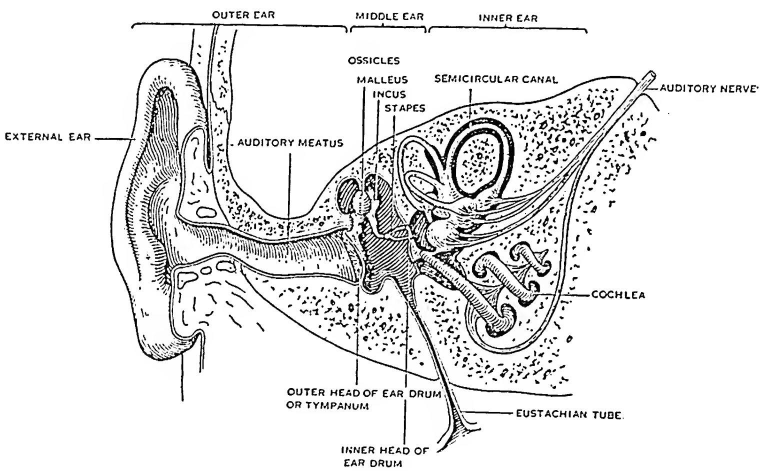


Figure 43. LONGITUDINAL SECTION OF EAR. (Schematic)

mit the mechanical energy of the air waves to the receptive organ buried deep in its bony cavity.

Middle Ear.

The membrane covering the opening of the inner ear separates it from another cavity in the bone, known as the middle ear. The middle ear is filled with air. The outer side of this cavity, like the inner, is closed with a membrane; hence the name "ear drum" is also often applied to the middle ear. The outer membrane, or tympanum, is a much larger, thicker, and tougher membrane than that directly opposite which covers the inner ear. The tympanum is in contact with the surrounding air, for it is placed across the

end of the canal leading into the side of the head. This external canal and the aural appendage around it constitute the external ear. The cavity of the middle ear is in communication with the back of the nasal passages through a small canal, the eustachian tube.

Sound waves striking upon the tympanum cause it to vibrate. These vibrations are transmitted to the membrane covering the inner ear by a system of minute bones acting as levers. The fluid of the inner ear is thus set in motion by the vibrations striking the tympanum. The conducting system is made up of three levers called, from their shape, the malleus, or hammer; the incus, or anvil; and the stapes, or stirrup. The handle of the malleus is attached to the tympanum, and its head to the body of the incus, which extends to a point a short distance back of the center of the drum. The hammer and anvil at their junction move upon the upper wall of the cavity as a fulcrum. The stapes serves to connect the tip of the incus to the membrane of the inner ear. Excessive motion of the lever system is restrained by ligaments attached to the bones and anchored in the sides of the cavity.

Deafness.

The common types of deafness are caused by stiffening of the lever system as a result of infection or damage to the middle ear. Only rarely is there any serious derangement in the carefully protected inner ear. In persons who are born deaf the cause usually lies in imperfect development of this organ.

In order that the tympanum may function it is necessary that the air pressure on each side of it should be equal. The air pressure within the middle ear is regulated by the eustachian tube which communicates with the throat. The eustachian tube is closed during quiet breathing, but is opened during swallowing, talking, or when a deep breath is taken. Opening as it does into the throat, the eustachian tube is frequently involved in head colds and catarrh. Thus temporary deafness may occur during a severe cold; for owing to inflammation, the eustachian tube cannot open to equalize the air pressure in the middle ear. In consequence the tympanum is pressed out of shape and the acuity

of hearing is dulled; the condition is sometimes accompanied by the sensation of "ringing" in the ears. The inflammation may travel up the eustachian tube and cause an infection of the middle ear. This is a serious condition; the cavity of the middle ear becomes filled with pus, and it is necessary to drain it by puncturing the tympanum. Middle-ear infection is very painful; if it goes unattended, the tympanum may be ruptured by the pressure of the collecting pus.

An additional danger from middle-ear infection lies in the possibility of the inflammation extending into the cells of the mastoid bone. This bone forms the ridge which can be felt on the side of the head directly behind the external ear. The mastoid bone is outwardly a very solid bone; but it contains cavities connecting with the middle ear. There is no way of draining pus from the cavities of the mastoid except by chiseling the bone away. If this "mastoid operation" is not performed soon enough the infection may spread to the membranes of the brain and cause death by meningitis; this fact illustrates the surgical rule that "pus under pressure is dangerous." This serious operation leaves a scar and depression immediately behind the ear.

For men who enter caissons where the atmospheric pressure is increased it is important that the eustachian tube should open freely. If the tube is occluded the tympanum is forced inward by the air pressure, causing severe pain and even rupture. When going "into the air" they swallow repeatedly, or even hold the nose and blow.

The tympanum is sometimes ruptured by the concussion of explosions. In children this rupture may result from a blow with the hand over the external ear, "boxing the ears." The same corrective measure applied to other portions of the body is equally effective morally and far less dangerous.

Outer Ear.

The outer ear is made up of the appendage known as the pinna or concha, from which a passage leads to the tympanum. The concha serves little function in man except that of decoration; the passage, on the other hand, fulfills the important purpose of

protecting the membrane of the ear drum. The canal extends inward obliquely and projectile bodies entering the ear strike against the walls and are stopped. In its center the canal is slightly constricted so that foreign bodies inserted into the ear tend to stop midway. The walls of the canal are lined with hair and secrete a thick yellow wax, both of which tend to discourage the entrance of insects. In spite of these obstacles, however, insects occasionally find their way into the canal and may even reach the outer head of the drum. They can at times be attracted out by holding a bright light at the opening of the canal. If this procedure fails oil or water heated to approximately body temperature (but no warmer) should be poured into the ear, and the insect thus drowned and floated out.

In some persons there is excessive formation of ear wax. Attempts to remove it with a hairpin, twisted end of a towel, or other home-made surgical instrument cause it to form in pellets, which are pushed in against the membrane of the drum. Temporary deafness is sometimes caused by the plugging of the canal with wax. If the secretion is out of reach of the index finger it should be removed only by a physician. Personal attention to the ear should be limited to regular cleansing of the concha for cosmetic reasons. There is a wise adage that "nothing smaller than the elbow should ever be put into the ear."

CHAPTER XVI
THE EYE AND ITS DEFECTS

Sight.

From an industrial standpoint sight is the most important of the senses. Those whose sight is impaired to any extent are correspondingly handicapped for most occupations. The eyes are delicate structures; yet in order to perceive light they are placed in an exposed position, and are therefore frequently subject to accidental injury. The eyes are also complicated structures which require accurate coördination of the various parts. Sight more than any other sense can be subjected to measurement and comparison in order to determine its defects. Whether we see far objects as well as those which are near; whether the printed page is blurred and a headache results from a period of close observation; whether shapes and colors are perceived correctly—such questions lead to evaluation of the individual's sight. Defects are very common, as shown by the number who wear eyeglasses. Nevertheless, it is likely that the sense of sight is subject to no more frequent individual defects than the other senses; it is simply that in almost every act we are dependent upon sight, and that its improper functioning, unless corrected, is a tremendous handicap. Thus we have learned that many children, and even workingmen, who have been accounted stupid and clumsy, are so because of poor eyesight and are greatly improved when this defect is discovered and corrected.

What is commonly called the "sensation of seeing an object" is in reality not a simple sensation, but is a perception built up in the brain out of innumerable separate sensations, and interpreted on the basis of past experience. At the back of the interior of the eyeball is a sheet of tissue known as the retina. It is like a mosaic in which each particle of the pattern is a nerve ending. These nerve endings are devices for receiving the energy of light and transmitting nervous impulses; each one when excited produces a separate and individual sensation. The sum total of all of these

sensations blended together forms the perception and thus the idea of the object which we see.

Light rays emanating or reflected from an object become more and more divergent the farther they proceed; in order to form a picture of the object upon the retina the light must be collected by refracting its rays in such a manner that they will focus upon the retina. This purely optical function of the eye is carried out in essentially the same way as in a photographic camera, by a system of lens surfaces or refracting media and a diaphragm. By varying the curvature of the surfaces, near or far objects are focused upon the retina. By varying the diaphragm, the intensity of the light admitted is adjusted to the conditions of illumination.

The common defects of vision are the results of imperfections of the optical system, and not of the retina, which, like the inner ear, is a remarkably perfect structure. Accidental injuries to the retina are much less common than are those affecting the optical system in the front part of the eye.

Structure of the Eye.

The eyeball is lodged in a bony receptacle, the orbit, which is cup-shaped. The walls of the orbit are thin, except at the margins, which are dense and strong. At the upper margin the skin is augmented by a cushion of hair, the eyebrow, which serves also to shed perspiration. Within the orbit the eyeball is bedded upon a layer of fat which allows free rotation of the globe. Six muscles extend from the walls of the orbit to the eyeball, and by their action impart lateral, vertical, and rotatory motions to the eye. The muscles of both eyes normally work in close adjustment with one another. Any incoördination in muscular action results in a squint, or "crossed eyes."

The movements of the lids are performed almost entirely by the upper lid; the lower is nearly stationary. In certain diseases the upper lid becomes partially paralyzed and droops; this condition called ptosis, gives to the face an expression of drowsiness and necessitates throwing the head back to enable light rays to gain entrance to the pupil. Similarly, the lower lid may relax and allow the tears which are constantly secreted to spill out across the face.

The inner surface of the lids is covered with a delicate tissue, the conjunctiva. This membrane is in the form of a pouch attached around the front of the eyeball, and turned back upon itself to line the insides of the lids. The conjunctiva covering the lids rubs against that upon the front of the eyeball, and these friction surfaces are lubricated by a continuous flow of tears. The gland which secretes the tears is located in the upper part of the orbit on the side away from the nose, and is like a small salivary

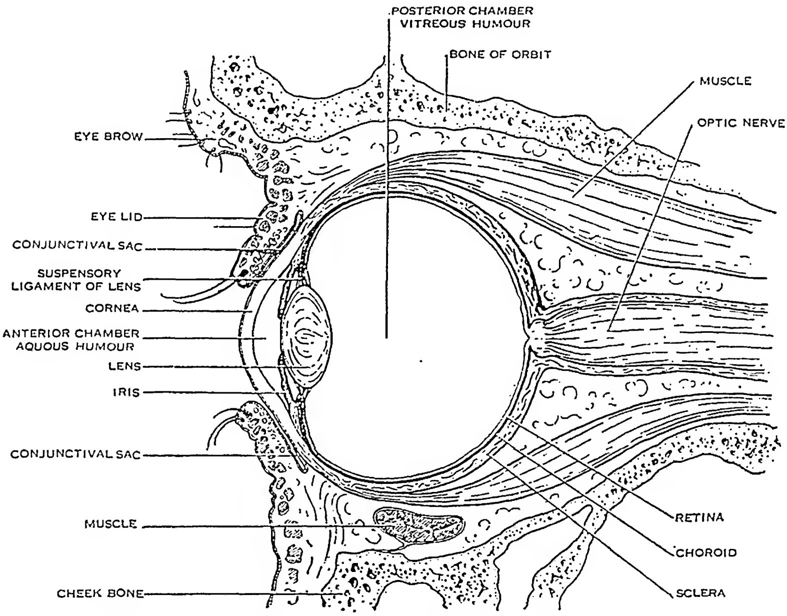


Figure 44. Vertical Section Through Eye and Orbit.

gland. It pours a slow stream of fluid beneath the lids at the outer and upper corner of the eye, so that the secretion runs across the whole surface of the eyeball and finally collects in the trough formed by the lower lid. Two minute openings at the inner junction of the lids lead into a tube ending in the nose, and the channel normally drains away any excess of tears. Flooding of the drain occurs when the formation of tears is excessive, either from emotion or from an irritation of the conjunctiva. The secretion first drips from the nose and incites the snuffling which accompanies weeping. When this normal channel of es-

cape becomes insufficient, fluid overflows the trough of the lower lid and courses down the cheeks as tears.

Beside their function of lubricating the surfaces of the lids and eyeball, the tears in their natural course serve to wash dust and larger foreign bodies from the surface of the eye to the opening of the drain. This action accounts for the accumulation of dirt at the inner corner of the eye which follows some hours after exposure to dust or smoke.

The eyeball itself is spheroidal in form, about an inch in diameter, and somewhat longer in its anteroposterior than its vertical axis, owing to the fact that the front protrudes as if a section

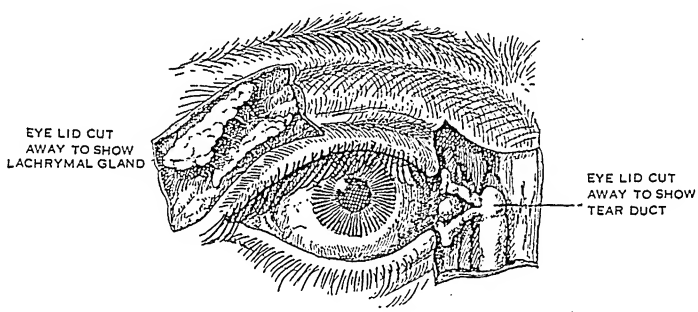


Figure 45. Lachrymal Apparatus.

The lachrymal gland, shown in the dissected area at the outer and upper side of the eye, pours its secretion over the front of the eyeball. The secretion is collected in the trough formed by the lower conjunctival sac (see figure 44), from which it is drained through the tear duct into the nasal passage (see also figure 25).

of a smaller sphere were here added on to the larger sphere. In structure the eyeball is a tough sac filled with a gelatinous material. The sac is transparent only in a small area at the front, and at this point are placed a lens and a diaphragm. The posterior half of the inner surface of the wall which forms the sac is lined with the retina containing the nerve endings sensitive to light. The nerve fibers leading from these sensitive areas are collected into a common trunk, the optic nerve, which emerges from the back of the eyeball and passes out of the apex of the orbit to its connections in the brain.

The outer layer of the eyeball is a tough membrane known as the sclera, the so-called "white of the eye." Lining the inside

of the sclera is a dark-colored coating, the choroid, which forms a base upon which rests the light-sensitive retina. To the outside of the sclera are attached the muscles which move the eye. In the center of the front of the eyeball the sclera is transparent, bulges out as mentioned above, and forms the cornea, or horny window of the eye.

The lens of the eye is placed close behind the cornea. It is biconvex like an ordinary magnifying glass, but is of such consistency and elasticity that its curvature may be altered; it is flattened by traction applied to its edges. A thin but strong membrane is attached all around the edges of the lens, and is in turn fastened at its periphery to the inner surface of the choroid near the edge of the cornea. The membrane attached to the lens is elastic; by its pull it tends to make the lens less convex and therefore of longer focus. A series of delicate fringe-like muscles stretch from the middle of the membrane and, passing forward, are attached to the choroid. When these muscles pull they draw the elastic membrane forward and thus oppose the tension which it exerts upon the lens. Being thus partially relieved of its lateral pull, the lens assumes a more nearly spherical shape and gives a nearer focus.

The amount of light which is admitted to the lens is regulated by the diaphragm, or iris. This structure is an opaque membrane with a central opening which forms the pupil. The iris contains muscle fibers by the action of which the size of the aperture is regulated. The color of the pigment cells in the iris determines the so-called color of the eye. In albinos the pigment is absent, and a pink hue is imparted to the iris by the reflection of the blood vessels in the choroid coat. All eyes are blue at birth; the commencement of permanent coloration takes place about the sixth week. Exposure to bright light before this time is harmful.

The lens and its supporting membrane divide the eyeball into two compartments—the small anterior chamber and the large posterior chamber. The anterior chamber consists of the space between the lens and the domed surface of the cornea; it is filled with a fluid, the "aqueous humor." The posterior chamber or space behind the lens is filled with a firmer jellylike substance called the "vitreous humor." The aqueous humor is slowly but

continuously secreted and drained away and the pressure within the eyeball is thus maintained uniform. Interference with the proper drainage leads to a serious condition known as "glaucoma," which will be discussed later.

Accommodation.

Light rays coming from a source at a distance greater than fifteen or twenty feet are nearly parallel. When the eye is at rest these parallel rays are refracted, that is, bent, by the surface of the cornea and lens to such an extent that they focus upon the retina. When the source of light is at a distance less than fifteen feet, the rays entering the eye are definitely divergent and must be more strongly bent in order to be sharply focused.

By "accommodation" is meant the alteration in the refracting system of the eye through which divergent rays from near objects are bent to the exact degree required to form a sharp image upon the retina. In a photographic camera accommodation, or focusing, is obtained by altering the distance between the sensitive plate and the lens. In the eye the same end is effected by changing the convexity of the lens and thus altering the refracting power. The increase in the curvature of the lens is accomplished, as already explained, by the pull exerted by a ring of radiating muscle fibers, the ciliary muscle, upon the membrane which is attached about the margin of the lens. The action of the muscle is opposite to the pull of the membrane, and so relieves the lateral tension upon the lens, which then by its own elasticity becomes more spherical. The important point in regard to accommodation is that, in order to see near objects, a muscular exertion is required; and the nearer the object the greater the exertion. Any performance involving the action of a muscle is subject to strain and fatigue.

As life advances, the ability to accommodate steadily declines. At thirty years of age, half the power is gone and at forty-five years it is so weakened that small objects near at hand are not seen clearly. At sixty years accommodation is practically *nil.* The decline in power is due to a progressive hardening of the lens and loss in elasticity, so that even when the tension of the marginal membrane is decreased by the pull of the ciliary muscle

the lens does not assume a more spherical shape. The power to see near objects distinctly and to read ordinary printing is thus lost, while distant objects are still seen clearly and without effort.

Visual Acuity.

Acuity of vision is determined by the angle subtended at the eye by the smallest object which can be seen clearly. Normal acuity is defined as the power to distinguish objects, such as letters, which subtend an angle of five minutes of arc. In conducting a test for visual acuity a card printed with letters of graduated size is placed before the eye, usually at a distance of twenty feet. A record is made of the smallest line of letters which the observer is able to read accurately with each eye separately. The rows of letters on the card are designated by the distance in feet from the eye at which they subtend an angle of five minutes. The larger the letters the greater the distance. The acuity of vision is commonly expressed by a fraction, the numerator of which is the distance at which the test is conducted, and the denominator the designation of the smallest type seen. Thus 20/20 means that at a distance of twenty feet the observer is able to distinguish letters which at a distance of twenty feet subtended an angle of five minutes upon the eye and, therefore, that vision is normal; 20/40 indicates that at twenty feet the smallest letters seen are those which at a distance of forty feet subtended an angle of five minutes (or about ten minutes at twenty feet) and, therefore, that the vision is only half of the normal.

Field of Vision.

A sharply defined real image is focused upon only a small portion of the retina. This area is particularly sensitive and is known as the macula. In order to bring the image of an object upon this spot, the eyes are turned either by the pull of their muscles or by movement of the head, so that they bear upon the object. Objects outside of this direct field of vision register only upon the retina surrounding the macula and are perceived in much less detail. Such indirect or peripheral vision is particularly susceptible to moving objects; they induce a reaction by which the main axes of the eyes are at once swung toward them.

Thus in crossing the street we may gaze straight to the front; but when an automobile is observed by peripheral vision or, as we say, "seen out of the corner of the eye," direct vision at once turns to the moving object. Direct vision permits the concentration of attention upon a limited field—an advantage not shared by hearing—while at the same time indirect vision acts as a sentry, causing no distraction of attention unless an object, presumably of danger, enters its much larger field. The reaction of the eye to moving objects leads to distraction of attention and ill effects to the eye itself as when shadows from moving machinery fall across the field of a man's work.

Binocular Vision.

The simultaneous use of both eyes is called binocular vision. It is by the blending in the mind of images focused upon nearly corresponding parts of the two retinas that the brain receives only a single impression. The eyes are far enough apart so that with the gaze directed upon any near object they form the base of a triangle; this permits an estimation of distance in a manner similar to that employed by a surveyor. By such triangulation we are enabled to judge the relative distance of two objects within a distance of about fifty feet of the observer; beyond fifty feet judgments of distance are based on sight combined with movements of the head, on perspectives, shadows, and other combinations of sensations. Beside the judgment of distance, binocular vision gives a perception of stereoscopic relations, the form and solidity of objects, chiefly through the fact that the retinal images of an object are not exactly the same in both eyes.

Movements of the Eyes.

If the harmonious action of the muscles moving the eyes is disturbed, single vision is no longer possible and double vision results. Paralysis of one of the muscles which move the eye is a common cause of cross-eye or squint. Persons who are very farsighted may show a squint when straining to view near objects. In long-continued squint the vision in the crossed eye is impaired or neglected and by this device of nature double vision is avoided. During the first year of life the purposeless

movement of an infant's eyes frequently show an alarming squint. This is unimportant, but any deviation which persists thereafter should receive attention.

Near- and Far-sightedness.

Light rays are converged by the refracting system of the eye and focused upon a point at a definite distance behind the lens. The length of the normal eye and the curvature of the cornea and lens are such that the focus falls exactly upon the retina. All eyes are not of equal length in relation to their focal distance, some being shorter and some longer than the normal eye. In an eye of subnormal length relative to its focus, the parallel light rays from an object at a distance are focused behind the retina, diverging rays of near objects are focused still further back, and only converging rays can be correctly focused. The short eye is therefore farsighted, or hypermetropic. In an abnormally long eyeball the point of focus for parallel rays is in front of the retina and only the diverging rays of near objects can be brought to bear upon the retina. The long eye is near-sighted, or myopic.

The length of the eye depends in large measure upon the shape of the skull and varies in different individuals and races. The skull which is short from front to back, as in the negro and American Indian, holds an eye which is short and therefore far-sighted. On the other hand, in the long skull of many Europeans, particularly Teutons, the eyeball is long and therefore near-sighted.

The farsighted person can obtain clear vision by increasing the curvature of the crystalline lens and bringing parallel rays to a shorter focus. An effort of accommodation must be made even for distant objects, while those with normal eyes need to make this effort only to focus the divergent rays on near objects. The extra degree of effort in accommodation involves a constant and excessive demand upon the ciliary muscle. In young and vigorous persons the strain may be maintained for a long time without perceptible disadvantage, but in older persons whose lenses have begun to harden, or in those with impaired health, symptoms of fatigue of the ciliary muscle manifest themselves. In mod-

erate degrees of farsightedness the strain is evidenced by blurring of the type in reading. In more severe degrees of farsight-

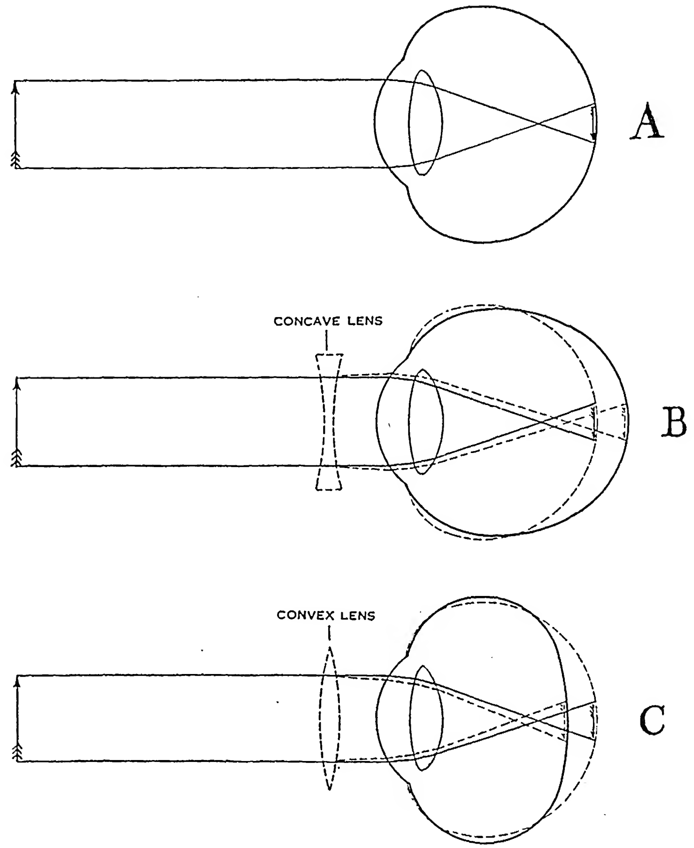


Figure 46. Correction of Eye Defects.

A. Normal eye. The image focuses upon the retina.

B. Nearsighted (myopic) eye. The eyeball is long and the image is brought to focus in front of the retina, that is, in the position of the normal retina as indicated by the dotted line. A concave lens of proper curvature restores the focus to the retina.

C. Farsighted (hypermetropic) eye. The eyeball is short and the image is brought to focus behind the retina, that is, in the position of the normal retina as indicated by the dotted line. A convex lens of proper curvature restores the focus to the retina.

edness the eye becomes congested, the lids and conjunctiva appear red and inflamed, while the eye is painfully sensitive to light, and headache follows any prolonged use of near vision.

Theoretically, the correction of farsightedness is simple. All that is necessary is to place before the eye a convex lens of such deviating powers that parallel rays are converged sufficiently to bring the resting focus upon the retina. Before a suitable lens can be selected, however, it is necessary to determine the degree of farsightedness. In a person of forty years of age and over, the crystalline lens is so hard that the act of accommodation does not interfere with the estimation, and fairly suitable eyeglasses can be selected by the trial-and-error method used by opticians and optometrists. Such eyeglass fitters, usually found in optical and department stores, are quite distinct from physicians who specialize in diseases and abnormalities of the eye and are designated as ophthalmologists. In order to determine the degree of farsightedness in the eye of a person under forty years of age, it is generally necessary to abolish accommodation by the use of a drug of the character of atropine. A drop of the solution is placed in the conjunctival sac, from which it is absorbed into the eye and temporarily paralyzes the muscles of accommodation. The use of drugs is properly forbidden by law to opticians and optometrists.

All old persons are farsighted, that is, they cannot accommodate sight to near objects. Parallel rays from distant objects are perceived clearly, but in order to read or see near objects they must use a convex lens. It is persons with this type of farsightedness, called presbyopia, who purchase suitable glasses from novelty stores or through mail-order houses, wear them with apparent comfort, and in emergencies borrow the glasses of another person similarly afflicted with presbyopia. Although this haphazard method of correcting refraction seems to be borne without serious harm by those whose optical errors result only from age, when attempted by a person of less mature years it may have serious outcome. Vision is our most highly cherished sense; the correction of its errors is a serious procedure and one which should be intrusted only to the most skilled ophthalmologist available.

Diametrically opposite to the farsighted eye is the nearsighted, or myopic, eye, for in this anomaly of refraction the eyeball is relatively too long for the focus, and light rays from distant

objects are focused in front of the retina. Although the farsighted eye may secure clear distant vision by the act of accommodation, a similar effort in the nearsighted eye only accentuates the difficulty. The myopic person is entirely dependent upon the artificial aid of lenses to see distant objects clearly.

Myopia is rarely present at birth; it generally develops about the eighth or tenth year. Its appearance at that time in eyes formerly normal or farsighted is usually traceable to hereditary influences determining the shape of the eyeball, to unusual strain upon the eyes from overuse or improper conditions of lighting, or to ill health. The normal eye may become nearsighted by the stretching of its coats from prolonged application to work which taxes the sight. Inefficient lighting and detailed work are therefore large factors in causing myopia. Nearsightedness tends to increase progressively from year to year up to the ages of twenty or thirty years, and in some cases throughout life. Although there may be but slight strain placed upon the mechanism of accommodation, uncorrected nearsightedness may give rise to headache and other symptoms of eye strain.

On account of their poor vision, myopics without glasses are greatly handicapped. Individuals with this type of eye defect often manifest a strong distaste for all sports and outdoor occupations and acquire a marked predilection for indoor occupations, painting, writing, watch-making, or other fine work. This taste is especially unfortunate, as prolonged near work aggravates their ocular deficiency. In consequence of their inability to observe the expression of those with whom they come in contact, those with myopia often develop an abstracted and even stupid expression of countenance and are usually diffident.

In the elongated eyeball of the myopic the vitreous humor may be inadequate in volume and may partially disintegrate, becoming fluid and more or less filled with opaque particles. These opacities float to and fro with movement of the eyes and occasion the motes which are a source of great annoyance to the nearsighted. Finally, as a result of the lack of support from the altered vitreous humor, the retina may become detached from the choroid coat in places. The result is a loss of sight in the area of the detachment.

Myopia demands the most careful consideration, not only by the physician, but by the layman as well. There is a more or less general impression that nearsighted eyes are stronger than others on account of ease in reading and in doing detailed work. Myopics are inclined to use their eyes at close work beyond reason. Often it may appear that the tax is without deleterious consequences, for the eyes apparently tolerate years of abuse without giving signs of failing; but by middle life the changes wrought by misuse usually manifest themselves. The prevention and correction of myopia have, therefore, a sociological as well as a medical significance.

Prevention of myopia includes an intelligent avoidance of eye strain, employment of proper lighting, and correction by glasses of any error of refraction. Most cases of myopia develop during school age and careful attention should be given to the avoidance of eye strain at that period of life. Many persons think that the use of glasses weakens the eyes. On the contrary, the most potent factor preventing the progress of ocular defects, once they have been initiated, is properly adjusted glasses. Errors of refraction, if permitted to go uncorrected, increase steadily and rapidly.

Myopia is corrected by placing before the eye a concave lens which causes parallel rays to diverge. The same care in selection of the proper lens is necessary as is the case for farsightedness. The tendency of myopia is to increase, and reëxamination and readjustment of the lenses should be made each year, until a comparatively stationary condition has been reached. After that examination every two or three years is ordinarily sufficient.

Nearsighted individuals can always see near objects clearly and they can, therefore, continue to read after accommodation is lost through the presbyopia of advancing age. For this reason there is a strong impression that nearsighted eyes grow stronger with age. This is not true; lenses should be worn. The so-called "second sight," or ability acquired by some individuals to read late in life without the aid of glasses, is really a symptom of cataract and is due to the swelling and increase in refractive power of the lens, which is one stage of this disease.

Astigmatism.

Astigmatism is the name applied to an error of refraction caused by an irregularity in the curvature of the cornea. The cornea, as explained above, is the transparent area in the front of the eyeball which resembles a small watch crystal. Light rays striking the cornea are bent from their straight course and this bending or refraction is completed by the crystalline lens. If the curvature of the cornea is regular in all meridians the light rays are bent uniformly, but if the cornea has an irregular curvature (*i.e.,* of different radii) the light rays are unequally refracted and are not properly focused. Details appear blurred to the eye afflicted with astigmatism; the objects are hazy about the edges just as in a photograph out of focus. If an astigmatic person closes one eye and gazes with the other at a diagram made to resemble a wheel with spokes, the spokes in certain directions appear much darker and clearer than in others.

The symptoms of eye strain are very readily induced by astigmatism in consequence of the effort made to focus rays of different length. Persons with this defect of refraction frequently contract the lids and turn the head to one side in an effort to obtain sharper vision. Headache and other forms of nervous disturbance are common. Poor vision due to astigmatism is often erroneously attributed to nearsightedness; but no form of spherical lens, either convex or concave, will improve such vision. What is needed is a glass with a cylindrical lens, which augments the refraction in the flatter meridians and thus compensates the defects of the cornea.

The correction of astigmatism calls for great care, for faulty correction may be more harmful than no correction at all. Furthermore, glasses containing a cylindrical lens must be held firmly in the frame to prevent accidental rotation and a consequent shifting of the cylinder, which would aggravate instead of relieve the astigmatism.

Influence of Eye Defects upon General Health.

Any decided derangement in the eyes themselves or in the balance of the ocular muscles may exert a profound influence upon the general health. The eyes are closely connected with the

nervous system and any disturbance in the eye may irradiate and cause malfunction in seemingly remote organs. These reflex symptoms rarely occur except in persons who use their eyes in close work for many hours each day. At times, however, they are encountered even in persons who lead an outdoor life with a minimum of eye strain.

Probably the most common symptom caused by eye strain is headache. It has been estimated that nearly three-fourths of the persons who consult oculists suffer from some form of head pain. The pain of eye strain may occur in any part of the head and therefore cannot be established by its location. The time at which the headache occurs is significant, however. A morning headache is induced by prolonged use of the eyes on the previous night in one person, while in another the headache will appear in the afternoon after a day at the desk, whereas on Sundays or holidays there is freedom from symptoms. Headache is just as apt to be induced by the strain of regarding distant as near objects. In some individuals headache appears in the morning after an evening spent at the theater, or it may be occasioned by watching moving objects, as in crowds, or passing objects when the person is riding in a car or automobile. Disturbances of digestion are also induced by eye strain. These may vary from flatulency, faulty digestion and its product constipation, to nausea and even vomiting. Uncorrected errors of refraction and eye strain may also have a detrimental influence upon the mental state and outlook. Pessimism, discouragement, and irritability may be greatly exaggerated by the nervous strain of perverted eyesight.

Influence of General Health upon Eyesight.

Just as eye strain influences the general health, so does any diminution in general health have its deleterious action upon the eyesight. Eye strain is exaggerated by ill health and the return of normal strength is hindered by the continued eye strain. The eyes should be used sparingly during convalescence from illness. Those who by the nature of their work suffer from eye strain should devote as many hours as possible to outdoor recreation and be careful of their general health. Certain diseases

have an especially weakening action upon the eyes. Of these, measles is perhaps the best known. Permanent defects of refraction may result from eye strain suffered during convalescence from this disease. Diabetes and disease of the kidneys may both react upon the eyes, and their injurious action is exerted especially upon the retina. The ophthalmologist is frequently the first to detect incipient disease of the kidneys from changes in the optic nerve and retina.

Color Blindness.

When a beam of light passes through a prism its rays are broken up into their component parts and the colors differentiated according to wave lengths. Color as such does not exist in nature, but is a sensation excited in the eye by light waves of different lengths. Inability to distinguish all the colors of the spectrum normally visible is called color blindness.

Color blindness may be total or partial, and either congenital or acquired. To those who are totally color blind the world appears as though it were tinted with different shades of gray, much as in an ordinary photograph. Total color blindness is rare, but partial color defect is common, occurring in about 4 per cent of all males, and probably somewhat less frequently in females. Color blindness is said to be hereditary. Acquired color blindness may result from any disease which causes changes in the retina or which interferes with the proper conduction of impulses from the retina to the brain. The most common cause is the immoderate use of alcohol and tobacco, a point of industrial significance in some occupations. Color blindness disqualifies for all occupations in which discrimination between colors is essential. It is a prohibitive defect for railroad employees, especially locomotive engineers, for naval officers and pilots, and for all occupations in the arts which require mixing pigments or matching colors.

As a rule those who are color blind, even those totally color blind, are unaware of the defect in their vision and it is sometimes only after careful test that the lack of color sense can be demonstrated. The common test used (Holmgren test) determines the ability of a person to match various colors in a series

of colored yarns. The set of worsteds employed for this purpose consists of (1) three chief test colors, a pale green, a light pink, and a bright red, (2) a series of lighter tints which color-blind persons are apt to confuse with the test colors. The person under examination is given one of the chief colors and told to pick out from the mass all those colors which contain the same tint. The man with a normal color sense has no difficulty in discriminating; but the color-blind person confuses red with green, and even with such tints as drabs, grays, and browns. The Holmgren test is sometimes supplemented by a lantern test. In front of the lantern is a disc upon which are mounted glasses of the various colors used on the railroads and in marine signals, such as white, red, green, and blue. These glasses are placed in front of the light of the lantern in rapid succession. The color blind are frequently able to differentiate colors by their different intensities. Therefore the intensity of the illumination must be carefully regulated. The lantern is placed twenty feet from the observer in a darkened room and the observer is required to recognize and name colors in a size which at that distance subtends a visual angle of five minutes.

Those who have acquired color blindness from the abuse of alcohol and tobacco may at times recognize colors correctly, provided the object upon which the color is exposed is sufficiently large; but they are not able to meet the stringent requirements of the lantern test. Candidates are frequently dissatisfied with the yarn test (Holmgren test), as they imagine that their failure is due to their inability to name the various tints exposed to them; but as a rule they are satisfied with the results obtained from the more familiar colored lights in the lantern.

Inflammation of the Conjunctiva.

In the section dealing with the structure of the eye, the conjunctiva was described as the delicate membrane which lines the lids and turns back upon the eyeball. Inflammation of the conjunctiva is known as conjunctivitis. In general, there are two types of conjunctivitis—that caused by bacterial infection of the conjunctiva, and that due to eye strain and to the irritation by foreign bodies or fumes.

The growth of bacteria upon the conjunctiva excites a secretion which varies in character according to the intensity of the infection. The more virulent bacteria induce a thick yellow discharge of pus, while mild growths occasion a mucous or catarrhal exudation. The discharge from all forms of bacterial conjunctivitis is contagious. Infection of the eyes of one individual from those of another afflicted with bacterial conjunctivitis results from bringing the germs into direct contact with the unaffected eye by means of soiled fingers or articles contaminated by the discharge. It can occur also through the medium of windblown dried secretion from diseased eyes. The first of these modes of infection occurs in both forms of conjunctivitis; the second only in the mild catarrhal type. These two types of transmission account for the fact that the more virulent forms of conjunctival infection, unless propagated by unusually bad hygienic conditions, generally occur singly, while the catarrhal forms of conjunctivitis frequently run in epidemics. Simple catarrhal conditions may also be excited by the action of irritants, such as foreign bodies, high winds, smoke, certain fumes and gases, and heat and light rays. Uncorrected errors of refraction are also potent causes of mild but persistent inflammation without bacterial infection. This condition resists all local treatment until the proper lenses have been obtained.

Diseases of the conjunctiva are among the most common affections of the eyes. All types cannot be described here. Those of special importance, however, should be known to persons supervising employees, for these diseases may be controlled or prevented by simple hygienic measures.

Ophthalmia of the Newborn.

Under this name are included all inflammatory conditions of the conjunctiva of the newborn baby, conditions which by reason of their severity are responsible for at least 25 per cent of all blindness throughout the world. Ophthalmia neonatorum appears usually on or before the fifth day after birth, as a redness and swelling of the lids, with a discharge of fluid. The redness and swelling rapidly increase, and the discharge becomes thick and abundant. On the third or fourth day of the disease

the lids are so swollen that they can be forced apart only with difficulty. The lids and eyeball are covered with a thick creamy pus. If untreated, the intense inflammation irritates the cornea, which loses its transparency and may be corroded through. In such cases the disease runs a course of several weeks, the inflammation subsides gradually and the lids are open again, but over scarred and sightless eyes. The disease is very contagious and if the discharge enters the eyes of an adult or older child, it excites an even more serious inflammation than that which affected the eyes of the newborn baby.

This distressing disease is caused by infection of the eyes of the child during the passage of the head through the vagina of an infected mother or by infection of the eyes soon after birth by a careless nurse. The germ most frequently responsible for ophthalmia neonatorum is that which causes gonorrhea. The condition of the eyes is then really gonorrhea of the eyes acquired by the child from a mother infected with this disease at the time of the child's birth. But not all cases of inflamed eyes after birth are due to venereal disease, for germs of a totally different nature may gain access to the conjunctiva and induce nearly the same effects. It is estimated that the germs of gonorrhea are responsible for 60 per cent of all cases of ophthalmia neonatorum; other types of bacteria for the remaining 40 per cent. Owing to uncertainty of the cause, it is not just to brand the parents in every case of ophthalmia with the opprobrium that many persons attach to venereal disease.

Ophthalmia neonatorum is prevented by what is known as the Crede treatment. A drop of a dilute solution of silver nitrate is placed in each eye of the infant within a few hours after birth. An irritation of the eyes frequently results from the silver nitrate, for excess may do harm, and unless this condition clears up within a day or two an ophthalmologist should be called in to examine the baby's eyes. Equally important is the immediate treatment of the condition once it has made its appearance. Every hour of delay adds to the danger. The outcome of the ophthalmia depends entirely upon the progress which the disease has attained when the eyes come under the care of

an ophthalmologist, for if proper treatment can be instituted within the first day or two, sight can generally be saved.

The infection may be carried by towels, handkerchiefs, bed linen, or other articles contaminated with pus by persons with gonorrhea. The transmission of gonorrheal conjunctivitis and also of trachoma, which is to be discussed later, constitutes the greatest objection to the use of a common towel. The use of the once familiar roller towel in public places is prohibited by laws in most states, but this efficient conveyor of eye infection is still to be found in some factories, stores, and occasionally in schools.

There is always danger that persons afflicted with gonorrhea will infect either their own eyes or those of their fellow workers through uncleanliness or lack of caution. The present opprobrious attitude toward the venereal diseases makes those who are affected unwilling to disclose the fact; it is therefore impractical to control their actions by law, so as to prevent the spread of infection to their eyes and to the eyes of their associates. The only practical preventative at present is to provide every sanitary facility in urinals and washrooms. The latter should be equipped with faucets which turn on by pressure of the knee or foot rather than the hand, individual paper towels or electrical drying machines, and doors fitted with kick plates instead of knobs or handles.

Trachoma.

Trachoma is an infectious disease of the conjunctiva which runs a prolonged course and results in the formation of elevated roughened areas, or granulations, on the conjunctiva and underlying tissue. The granulations later form scars. The cornea may be damaged and distortion of vision or blindness may result. The shape of the lids is distorted and frequently the lashes turn in against the eyeball.

In most cases this disease commences with symptoms similar to the purulent conjunctivitis described in the previous section. In some cases the granulations and scars develop with little previous inflammation. Trachoma is a chronic disease and continues with variations in intensity for many years. If it is recognized in its earlier stages, a cure can be effected; but the

treatment must be continued for a long period, a year or more, otherwise it recurs. Advanced cases of the disease are incurable, but treatment serves to prevent increase in the severity of the condition, and to delay blindness.

Trachoma is extremely contagious. The infective material is contained in the discharge from the eye and is conveyed to healthy eyes by dirty fingers, soiled towels, bed linen, flies, or any article of common contact. Trachoma is a disease of poverty and squalor. The crowding together of a large number of people without the possibility of maintaining personal cleanliness is responsible for the rapid spread of the disease. Hence the Jews of Russia and Poland are frequently affected. The disease is common in Ireland and in almost all the southern European nations. It is estimated that 90 per cent of the population of Egypt are afflicted with trachoma. To the traveler one of the most striking features of the people of Egypt is the immense number who are blind and going blind. The disease was introduced into the United States by infected immigrants. In 1897 the government found the spread of the disease from this source to be so rapid that a law was passed requiring the examination of the eyes of all immigrants, and making mandatory the deportation of persons with trachoma. The law came too late for trachoma had already gained headway in the country. Jewish peddlers and tailors, and Italian and Slavic laborers in mines and mills, have spread the disease, so that there is no part of the country where trachoma is not found. The greatest number are in the large maritime, manufacturing, and mining sections. In addition to the spread of this disease among the foreign population, it has a fertile field in certain sections of the native population. Trachoma has become common among the American Indians and the mountaineers of Kentucky, Virginia, and West Virginia. It is estimated that 20 per cent of the Indians are infected. In Kentucky there are 33,000 known cases.

Although trachoma in its advanced stages is easily recognized, its early stages can only be detected by a trained ophthalmologist. There is a common and harmless disease of the conjunctiva which must not be confused with trachoma. This disease is known as follicular conjunctivitis and is usually called

"granulated eyelids." The granulations, while bearing some resemblance to those of trachoma, do not give rise to an infectious secretion and the entire condition clears up without leaving any permanent injury.

The prevention of trachoma requires the removal and isolation of infected persons and other sanitary measures to prevent the contamination of healthy eyes. No matter how scrupulously hygienic conditions are maintained in the factory, it is necessary, in order to prevent the spread of trachoma, to extend the education into the homes and community life of the employees.

Pink Eye.

This form of conjunctivitis occurs most commonly in the spring and fall and usually as epidemics in factories, schools, and institutions. The disease is very contagious. The infection is spread by the discharge from the eyes or by the scales formed from the dried secretion carried by the wind. The inflammation commences with redness of the lid and eyeball and an increased flow of tears. By the third day the lids are swollen and the discharge thick and tenacious. The disease runs a course of about ten days or two weeks, and is usually followed by complete recovery. In occasional cases ulceration of the cornea results, so that the disease should always be treated by a physician.

Cataract.

Light in entering the eye passes through the crystalline lens. If the lens becomes opaque, light cannot pass through it and vision is lost. This loss of transparency occurs in the disease known as cataract. The development of the opacity is slow and the loss of vision progressive. In its early stages the change is imperceptible to anyone looking at the eye, but in the later stages the pupil has a grayish color. A cataract should not be confused with a growth or scar upon the surface of the cornea; neither is it, as is sometimes supposed, a membrane which forms over the eyeball. It is the lens itself which changes; it is as if a clear glass lens had become frosted, but the opacity is in the substance of the lens, not on its surface.

Cataract may occur at any age, but most commonly in infancy

or old age. Infants are sometimes born blind because of cataract; in old age there is nearly always more or less fogging of the lens. There appears to be a hereditary tendency for the development of cataract, particularly of the type which appears in infants. Workmen who are constantly exposed to intense light may develop cataract as a result.

No medicine will cure cataract; nothing will dissolve the opacity of the lens and restore its transparency, although charlatans sometimes claim to do so. Cataract is treated by removing the lens by a surgical operation, and then fitting the eyes with spectacles having a powerful convex lens. Some measure of useful vision is thus restored; the man can see to read, to make his way about, and is capable of certain types of employment.

Glaucoma.

The aqueous humor which fills the anterior chamber of the eyeball is a form of lymph. It is continually secreted and drained away through lymphatic vessels. The drainage takes place through minute channels which open into the anterior chamber at the point where the outer edge of the iris meets the cornea. The proper balance of pressure within the eyeball is maintained by the rate at which the humor is drained away. In the disease glaucoma the escape of the fluid is hindered by stoppage of the drainage canals. The fluid accumulates, and the eyeball becomes tense and hard. This increased pressure is disastrous to sight, for the tissues of the eye, especially the retina, cannot long withstand the pressure and the obstruction to the circulation.

Glaucoma is a disease of middle life. It occurs in one or other of two ways—either as a rapid or fulminating type, or in a slower and chronic form. With the acute type of glaucoma there is intense pain in the eyes. Sight rapidly decreases and may be lost in a few hours, and may never be regained unless an operation is performed at once. The chronic form of glaucoma does not give rise to pain and immediate loss of sight. The person afflicted may notice nothing more serious than some difficulty in reading, which is usually attributed to a need for stronger glasses. The outcome of the condition then depends upon the

type of person consulted. An optician or optometrist will usually overlook the incipient disease and prescribe a pair of glasses, and perhaps a second, and even a third pair at later intervals as the loss of sight progresses. When medical aid is finally sought, after the delay caused by such refractive experiments, the disease has often progressed so far that little can be done to check it and retain even the vision that remains. Sight lost from chronic glaucoma is never regained. If an ophthalmologist is consulted at the first indication of failing sight, he will make an examination of the interior of the eye and at once detect the increased pressure. The opening in the sclera through which the optic nerve passes is the weakest point in the eye and is the first to give way when the pressure within the eyeball is increased. The ophthalmologist in making his examination will observe that the head of the optic nerve is pushed backward and a cup-like depression called "choke disk" is formed.

The operation for acute glaucoma consists in removing a segment of the iris, so that there will be a greater space for drainage at its periphery. The results of this operation are often little short of marvelous. Eyes which have been blind for hours or days are restored to almost normal vision. The operation was devised in 1856. Before that time blindness from glaucoma was inevitable. The chronic form of glaucoma is usually treated with drugs which contract the pupil and thus pull the base of the iris away from the cornea, thereby better exposing the drainage area. When the drug treatment fails to control the disease an operation is resorted to.

Foreign Bodies in the Eye.

Foreign bodies which reach the surface of the eyeball do not usually penetrate deeply into it, but are simply lodged upon the conjunctiva. Bodies of this type may move about on the surface of the eye, thus scratching the cornea and setting up inflammation and possibly a later infection. Infection of the cornea leads to a roughened ulcerated area which may become opaque when it heals. Scars on the cornea may permanently interfere with sight. When the foreign body is forcibly projected against

the cornea and is imbedded in its surfaces a wound results from which the consequences are similar to those of a scratch, but more serious. Such projectiles are most commonly flying metal chips or particles thrown from an emery wheel.

Usually no serious injury to the cornea results from a foreign body on the surface of the eyeball. Serious injury and infection are, however, frequently caused by attempts of unskilled persons to remove the foreign body. Every shop boasts a "handy man" who is apt at removing foreign bodies from the eyes of his fellow workers. Such a man frequently is a serious menace to the sight of those upon whom he operates. The ideal factory system is one which has an ophthalmologist or trained nurse on its staff to whom all eye injuries, even the most insignificant, are at once referred. If a freely movable foreign body must be removed without medical assistance, a clean handkerchief moistened at the corner with water, but never with saliva, should be used to wipe it off the cornea. If the foreign body cannot be dislodged from the cornea by gentle contact with the handkerchief, medical aid should be sought. Such instruments as toothpicks, blades of knives, horse hairs, and the like should never be used to remove foreign bodies from the eye. Serious injury has resulted from such practices.

Splinters of metal are sometimes projected deeply into the cornea or may even pierce it and pass into the anterior chamber of the eye. No first aid attempt should be made to remove such splinters. If the metal is one which responds to the action of a magnet the skilled physician will use this means to draw it from the eye. The removal of metallic objects from the eye by means of a magnet is a delicate operation. There is always the possibility that the fragment has passed entirely through the cornea and is lodged in the anterior chamber; its removal will then occasion a second and distinct perforation. Care is necessary to avoid bringing this wound in the optical center of the cornea for the scar which results may then impair vision. The practice of exposing the eye to the field magnet of a dynamo or motor in a machine shop, as a means of removing steel chips, has resulted in many injuries to the eyes that could and should have been avoided.

Perforating Injuries.

The eye may be struck against any sharp pointed tool or projection, or these may be thrust into the eye. In this field there are two chief offenders: the sharp-pointed upright paper spindle used to impale loose paper slips; and the straight-spout oil can. Injuries to the eye occur when an individual leans too close over or falls face down upon these instruments. There are many cases on record where desk workers have fallen asleep, their heads have drooped forward, and the eye has been speared through with the paper spindle. Accidents from spindles and oil cans can be avoided by using such equipment with the tip bent over instead of upright.

The greatest danger from perforating eye injuries lies in the possibility of sympathetic involvement of the uninjured eye. If one arm is seriously injured the sound arm does not in consequence become inflamed or irritated. But the two eyes are so closely bound together in their action that injury to one frequently results in an inflammation in the uninjured eye. If sight is lost in one eye through a perforating injury, surgeons usually consider it necessary to remove that entire eye. Such removal, called enucleation, stops the spread of the inflammation to the other eye and prevents total blindness.

Injury by Light and Heat.

Exposure to excessive heat or light constitutes another cause of injury to the eye. Incandescent molten metal, the electric welding arc, and the play of the oxyacetylene flame upon metals are sources from which arise harmful ultra-violet and infra-red rays.

Workmen exposed to intense heat or light radiations should always wear protecting goggles. Electric welders should be equipped with complete helmets, absolutely light-proof except for the ocular apertures, which are covered with specially tinted glass. Men who make only occasional inspections of an intensely heated surface such as that in the open-hearth furnace may use, instead of goggles, a glass mounted in a frame, which is held in the hand.

A special form of glass is used to protect the eyes from the

harmful infra-red and ultra-violet rays. It is, however, impossible to make a glass which will absorb sufficiently both the infra-red rays and the ultra-violet without cutting down the visible light so that it is difficult for the employee to see his work. Moreover, the glass, by absorbing the heat radiations, soon becomes hot and then gives off radiations of its own close to the eye, thus defeating its purpose.

Recently a glass, known as the Pfund lens, has been developed which appears to overcome in a new way the difficulties ordinarily encountered. The Pfund lens consists of a piece of Crookes glass coated with an exceedingly thin layer of gold. This gold layer is in turn protected by a piece of crown glass. All radiations except the extreme ultra violet pass through the crown glass. Encountering the gold layer, the ultra violet and the visible radiations up to about the middle of the red pass without difficulty. At the middle of the red region of the spectrum the light rays become too long to pass and are reflected from the gold surface. Thus all the infra-red rays are radiated back and are not absorbed, as is the case with the usual protective goggles. The ultra-violet rays which pass the gold layer are absorbed by the Crookes glass. The amount of visible light admitted can be regulated by varying the thickness of the gold plate. As ordinarily made the coating is of such thickness that 25 per cent of the visible light is passed. The lens can be made to pass 75 per cent without seriously decreasing the efficiency of the protection.

Peculiarities of Light Perception.

The relation of the intensity of light to perception is illustrated by a person reading in a room artificially lighted from a single very brilliant source. At some distance from the light the print cannot be distinguished; on moving nearer to the light the print becomes increasingly legible until finally a point is reached very near to the light beyond which no increase in legibility can be attained, and the eyes are made uncomfortable by the excess of the illumination. At some point in the course toward the light an optimal illumination is obtained. Evidently the optimum is less than the maximum. In industrial work it is this optimum which

is desired, but its attainment for work of varying character is beset with many difficulties.

Perception of difference in intensity of light is the basis of many of our acts of vision. In reading, for example, we are able to see the black print upon the white paper because the white reflects to the eye some 80 per cent of the light thrown upon it while the black returns but a fraction of 1 per cent. The delicacy with which the eye can distinguish the intensity of light is determined by the relative amount contributed by each object to the total illumination (Weber's law, Chapter XV). An electric light appears at night to give a brilliant illumination, but when viewed in the daytime it seems feeble. The intensity of the perception of light is largely a matter of contrast. A source of light of moderate intensity placed against a dark background may have sufficient contrast to prevent the perception of surrounding details. The light then is said to glare.

The eye is constantly exposed to sources of light which vary greatly in intensity. Within limits the eye adapts itself to the lighting by altering the size of the pupil. Under very brilliant illumination the pupil is contracted until it is not much larger in diameter than the head of a pin; in very dim light the pupil is expanded until the iris becomes merely a thin line of color. The amount of light admitted to the retina varies as the square of the diameter of the pupil. The changes in the size of the pupil are automatic and not under the direct control of the will. The alteration is initiated by the action of the light upon the retina and is carried out through a nervous reaction. There is a slight lag between the change in intensity of illumination and the response in the size of the pupil; everyone has stepped from a lighted room into partial darkness, and has then observed the gradual appearance of details as the pupils expand. Conversely, on passing from the dark into a brightly lighted room one is blinded by the glare, until the pupil has contracted to suit the greater illumination.

The nerves which actuate the irises of the two eyes are connected so that the pupils change together. This is largely true even though the light strikes only one eye. In some animals, notably the horse and mule, each iris acts independently. In

using these animals for haulage in mines it is the practice to put a pad over one eye whenever they emerge into the daylight. The covered eye remains dilated. On returning to the mine the pad is removed and the animal sees easily in the partial darkness without the necessity of delay for readjustment of the iris. This procedure is often imitated by miners on themselves under similar circumstances, but the benefit derived is imaginary, for the covered pupil contracts in response to the light which acts upon the opposite eye.

Whenever a moving body enters the field of vision the eye turns to it and brings it into the line of direct vision. This reaction gives rise to distraction in industries where moving lights or shadows pass before the workers. In the extreme degree, occurring in mines, this condition may result in a disease known as "miner's nystagmus," in which the eyes constantly oscillate even in daylight. Persons thus afflicted are unable to work. The disease can be prevented by general illumination of the mine, so that there is less contrast between the moving lights of the workmen and the dark surroundings, and therefore less distraction of the eyes.

Room Lighting—Eye Sight and Illumination.

The blind man is an economic loss. From the blind to those with normal vision the value of any employee, other considerations being uniform, varies with the normality of the eyesight. Besides their economic importance, the defects of vision have their sociological and humanitarian aspects. Perhaps 15 per cent of all accidents occur as a result of inability to see normally; there are 15,000 deaths from falls each year in this country.

Illumination is an aspect of vision. The man with normal vision when placed in a dark room has no advantage over a blind man. The man with normal eyes can see the objects before him in proportion as the illumination varies from darkness to the optimum light. Lighting is therefore quite as important as normality of vision. It is incongruous that an employer, fully aware of the economic value of good eyesight, should have his factory poorly illuminated so that every employee works with only a fraction of normal vision. Faulty illumination leads to acci-

dent, to eye strain, and to the development and progression of errors of refraction among those who are exposed. From poor lighting there follow both loss to the employer and direct and avoidable injury to the workingman. The art of lighting factories, halls, and dwellings, called "illumination engineering," has made great progress in recent years. It deserves attention.

CHAPTER XVII
INTELLIGENCE, FEEBLE-MINDEDNESS, AND INSANITY

THE view regarding the mind to be here presented is that the mind is the expression of the activity of the brain to the same degree that digestion is the function of the alimentary tract, and that embryo and infant are the product of the reproductive organs. In other words, the mind is not something separate from the body, but is a function of one of its organs. The brain "secretes" the mind no less than the glands of the mouth secrete saliva and the kidneys secrete urine. The mind is as dependent upon the integrity of the anatomical structure and the normal physiological functioning of the brain as the circulation of the blood is upon the normality of the heart, its valves, and rhythmic action. Thus normal cerebral activity, consisting in the transmission of nerve impulses this way and that among the centers, is the process underlying the mind, or intelligence. Disturbances of the mind are to be regarded as the psychic and behavioristic aspects and expressions of abnormal cerebral functioning.

Intelligence.

Intelligence is the capacity for productive thinking, for reasoning accurately from premises—that is, for the brain on receiving certain sense impressions to work out a suitable reaction to a new situation of some degree of complexity. It is the ability to arrange the separate impressions gained from information and experience into a concrete product; the ability to build new responses with the material of thought, which the nervous system supplies, in contrast to mere learning by rote, parrot-like reproduction of rather simple acquired reflexes. The facility with which this process is carried out and the accuracy and complexity of the product depend upon the degree of intelligence. Not all adults are equally intelligent.

Intelligence is an inborn quality of the brain and mind. The

degree or level of intelligence attained by an individual depends largely upon inheritance; intelligence cannot be acquired. Every human being is born with a capacity for mental development which will permit him to attain some particular degree of intelligence, but no more. There is a progressive development of intelligence from birth to some upper limit beyond which the intelligence ceases to develop.

So far as can be determined, the development of intelligence is complete in everyone by the time physical maturity is reached. Not everyone continues to develop in intelligence, however, throughout the period from birth to maturity. Many, in fact the majority, stop at one or another of the lower levels during childhood, and remain at that level throughout life.

Intelligence should not be confused with knowledge. Some degree of intelligence is necessary to the acquisition of knowledge. Thus a normal child of thirteen years can acquire more complex information and in greater amount than a child of six or eight. The amount of knowledge may be out of all proportion to the intelligence. A man of relatively low intelligence may be a veritable encyclopedia of information; and yet, through the nonproductiveness of his intelligence, he may be unable to apply this information to new ends. Knowledge is not intelligence; it is the raw material upon which intelligence draws to synthesize its product. A man who has knowledge, but who is handicapped with a low degree of intelligence, may give a false impression of intelligence and capability. Yet he is incapable of success in a position requiring any considerable degree of intelligence. A man of relatively high intelligence, but with a lesser amount of knowledge, may at first be underrated, but he is soon found to be capable of acquiring knowledge and, furthermore, of applying it.

It is a long and expensive procedure to select men for various occupations by the method of trial and error. The American army was confronted with this difficulty in the European War. Several million men of all degrees of intelligence were drafted. From these men there were to be chosen those capable of becoming commissioned officers, non-commissioned officers, privates, and those unsuited to serve in the army. Tests were developed by which the intelligence of these men might be graded. Similar

tests had been in common use for judging the mental age of school children. The better known of these tests are that of Binet and the Stanford Revision. The former extends its norms only to the twelfth year, while the latter extends to "superior adults." The tests developed for use of the army were applied to 1,700,000 men. The findings were so closely in agreement with the experience of the officers handling the men that they were accepted and used as a basis for classification. Similar tests are useful up to a certain point in employing men in industry.

Measurement of Intelligence.

If any group of men chosen at random are tested for some physical quality, such as their stature, it will be found that a few are short and a few tall, but that the majority are of medium height. When the measurements are plotted with the abscissæ

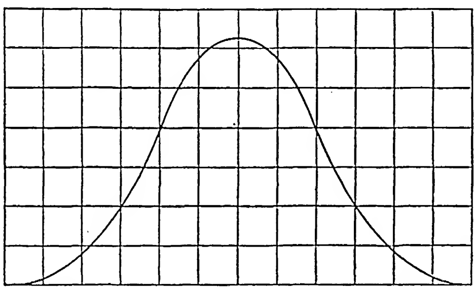


Figure 47. Normal or Gaussian Curve of Distribution.

representing stature, and the ordinates the number of men in the group corresponding to each height, a curve is obtained of the shape shown in Figure 47. It is the normal, or Gaussian, curve of distribution.

This curve applies to the distribution of any comparable qualities in a group of persons when all the members tested possess these qualities in some degree. Thus when the scholarship grades obtained by a class of college students are plotted and compared in this way, it is found that a few have failed and a few have achieved honors. A somewhat greater number have a good stand and about an equal number a poor stand. But the large majority fall in an average which is merely mediocre. Thus the grades fall in the curve of normal distribution.

Intelligence is a faculty possessed in some degree by all men. Therefore, any group whatever of unselected persons must give results corresponding to the normal curve of distribution, otherwise the method of examination is incorrect. Intelligence tests were created quite empirically; but their validity has been determined by this criterion. It cannot be said beforehand what questions will or will not be answered by any assumed degree of intelligence. The questions must be formulated, then tried and standardized on a large group of men. The only prerequisite is that the test shall demand only such information as the intelligence of the least intelligent member of the group would enable him to acquire. The results are simply comparative; they show which persons in a group are of average intelligence, and which are above or below this standard, and to what degree. The large number of men upon which the army test was standardized makes it one of particular merit. Not all so-called intelligence tests share this advantage.

In the army two main types of test were employed for estimating intelligence; the so-called beta and alpha tests. The beta was for men who could not speak English or who were illiterate. This test consisted of pictures, designs, number comparisons, and the like, and instructions were given in pantomime. The alpha test was used for men who could not only speak but also read and write English. The answers to 212 questions were written out by the men. In both tests the grades were assigned on the basis of the proportion of questions answered correctly, and ranged from D— for the lowest to A for the highest.

Figure 48 illustrates the results of the tests for intelligence made upon 1,700,000 men drafted into the army. The 1,700,000 men tested may be accepted as a fair sample of the population of the United States. In all probability the facts determined in respect to the army apply to the country as a whole. The ratings of the army tests were taken as an index of the relative ability of the men to learn, to think quickly and accurately, to analyze a situation, to maintain a state of mental alertness, and to comprehend and follow instructions. The scores were found to be little influenced by schooling. Some of the highest records were made

by men who had not completed the eighth grade. The significance of the letter ratings is as follows:

A.—Very superior intelligence. This grade was earned by only 4 or 5 per cent of the men. Those among these men who were also endowed with the necessary emotional quality made officers of the highest type. To attain grade A it was necessary to score in at least 135 of the total 212 questions in the alpha test.

B.—Superior intelligence. This rating was obtained by about 9 per cent of the men, and this group included many suited to be commissioned officers. A man of this grade is capable of completing a college course with an average record. A score of 105 to 134 points was necessary to reach this grade.

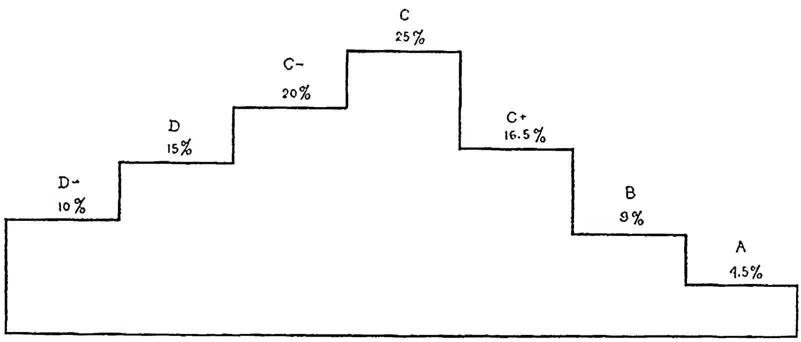


Figure 48. DISTRIBUTION OF INTELLIGENCE AS DETERMINED ON THE BASIS OF THE ALPHA TEST.

C+.—High average intelligence. This group included 16½ per cent of the men and contained a few suited to be commissioned officers and many to be noncommissioned officers. A grade of C+ required a score of 75 to 104 points.

C.—Average intelligence. This group included about 25 per cent of the men tested and furnished excellent privates and some noncommissioned officers. An intelligence of this grade is rarely capable of completing the high-school course. A score of 45 to 74 points was required.

C—.—Low average intelligence. This group included about 20 per cent of the men. They made good privates and were satisfactory at routine work. A score of 25 to 44 points was required.

D.—Inferior intelligence. This grade included about 15 per

cent of those tested. These men learned with difficulty, were deficient in initiative, and required more than the usual amount of supervision. A score of 15 to 24 points was required.

D—.—Very inferior intelligence. This group constituted 10 per cent of those tested. They were of such low intelligence that they had rarely been able to go beyond the third or fourth grade of elementary school, however long they attended. Many men from this group were relegated into still another group (E), as unfit for regular service in the army.

The alpha examination consists of eight tests. A careful explanation is made of each test before the men start to answer the questions. At the completion of the explanation the command to start is given, and the men are allowed to continue for a fixed time, when the command is given to stop. The first test consists of a series of commands given orally which are to be executed quickly. A typical command from the first test is to cross out all numbers over 50 but less than 60 in a series of ten numbers. The second test consists of twenty arithmetical problems for the solution of which five minutes are allowed. The problems are progressively more difficult, but none require more than the most elementary knowledge of arithmetic for their solution. The third test is one of practical judgment. A minute and a half are given in which to select the best of three answers given to eighteen such questions as: "If you do not get a letter from home which you know was written, it may be because: (1) it was lost in the mails, (2) you forgot to tell your people to write, (3) the postal service has been discontinued." The fourth test consists of forty pairs of words which are either synonyms or antonyms. A minute and a half are given in which to indicate the relation by underlining the words same or opposite. The fifth test consists of twenty-four sentences in which the words are disarranged. Two minutes are given in which to straighten out the sentences mentally and to indicate whether the statements they made are true or false. The sixth test consists of twenty series of numbers, with six numbers to a series. Three minutes are given in which to add to each line the next two numbers in the series. The seventh test consists of a series of forty analogies in which four choices are given for the last word to complete the analogy. Three minutes

are allowed in which to make the selection. The eighth test is one of simple information. Forty sentences are given, with four choices for the last word, as in the sentence: "Revolvers are made by Swift & Company, Smith & Wesson, B. T. Babbit, W. L. Douglas." Four minutes are given in which to underline the words selected.[1]

Relation Between Intelligence and Education.

A high grade may be obtained in an intelligence examination by a man who has had little schooling. This, however, is the exception. If all persons remained in school as long as they could continue to advance, their record of education would then constitute a fair criterion of their intelligence. Some persons, however, leave school for reasons other than their inability to do the required work. From this group come those whose rating on intelligence examinations is high in proportion to their education. The fact that a man has gone only as far as the sixth grade in an elementary school does not prove that his intelligence would have carried him no farther. But a man who has completed the sixth grade, high school, or college, must be credited with the intelligence requisite to complete these tasks.

The process of elimination which goes on from year to year in schools and colleges is severe. A study of the records of 80,000 native-born white recruits in the army showed the following: Of every 1,000 who entered grade one, 970 remained in school until grade two, 940 till grade three, 905 till grade four, 830 till grade five, 735 till grade six, 630 till grade seven, 490 till grade eight; 230 of these enter high school, 170 continue until the end of year two, 120 till the end of year three, and 95 graduate; 50 then enter college, 40 remain until the end of year two, 20 till the end of year three, and 10 graduate.

Persons of low intelligence have less wage-earning ability than persons of high intelligence. There is a relation between the three factors, intelligence, wage-earning ability, and education. In the following table are given the wages and the schooling of the American population compiled by the Departments of Labor,

[1] The alpha test slightly modified, and with full direction for taking it and also grading the results, is published under the title *Are You Intelligent?* by H. W. Haggard. Harper & Brothers, New York, 1927.

and the averages of intelligence as determined from the army examination applied to 1,700,000 men. The actual amount of the wage has no particular significance in view of the rapidly shifting scale of wages, but the relations of the amounts have not been materially altered.

TABLE VII

Wages per year	Education	Intelligence (army distribution)
9% earn $150–$ 200	13% leave in the 4th grade	10 % in D−group
12% " $250–$ 300	13% " " " 5th "	15 % in D "
16% " $350–$ 400	14% " " " 6th "	20 % in C− "
31% " $450–$ 600	27% " " " 7th and 8th grades	25 % in C "
27% " $750–$1000	23% leave after the 8th grade	16½% in C+ "
3% " $1250	10% attend high school	9 % in B "
2% " over $1250	3% graduate " " 1.5 " college	4½% in A "

Efficiency in Relation to Intelligence.

It is fundamental for efficiency that a man should work at an occupation which is on his own mental level. If the task requires less intelligence than the man is capable of exercising, he works at a loss; if the task requires more intelligence than the man possesses, he fails. Lack of intelligence sufficient to undertake a given type of work definitely establishes the fact that the man cannot succeed, but the reverse does not always follow. A given occupation which requires a definite degree of intelligence cannot be arbitrarily assigned to every man with the requisite intelligence with full assurance of success. The physique of the man must be taken into consideration; has he or has he not the eyesight, physical stamina, and health to work at the occupation, and also has he or is he capable of developing the muscular coördination necessary to the trade? And finally, is he endowed with the indefinite qualities of leadership, personality, and temperament suited to the particular employment? These qualities cannot (as yet) be estimated by any artificial test, but only from success or failure in practice. Intelligence is but one of the many qualities necessary to success in any occupation. It is, however, a basic quality which cannot be replaced by any amount of physical strength or manual dexterity.

Certain occupations require more intelligence than others. The

TABLE VIII

TABLE SHOWING OCCUPATIONS IN RELATION TO RATING BY THE ALPHA INTELLIGENCE TESTS

D – | D | C – | C | C + | B | A

C –	Laborer
	Gen. miner
	Teamster
	Barber
C	Horseshoer
	Bricklayer
	Cook
	Baker
	Painter
	Gen. blacksmith
	Gen. carpenter
	Butcher
	Gen. machinist
	Hand riveter
	Tel. and tel. lineman
	Gen. pipefitter
	Plumber
	Tool and gauge maker
	Gunsmith
	Gen. mechanic
	Gen. auto repairman
	Auto engine mechanic
	Auto assembler
	Ship carpenter
	Telephone operator
C +	Concrete const. foreman
	Stockkeeper
	Photographer
	Telegrapher
	R. R. clerk
	Filing clerk
	Gen. clerk
	Army nurse
	Bookkeeper
B	Dental officer
	Mechanical draftsman
	Accountant
	Civil engineer
	Medical officer
A	Engineer officer

D – | D | C – | C | C + | B | A

duties of a street-car conductor take less intelligence than those of a mechanical engineer or an accountant. Although there are many men who are mentally unsuited to the employment in which they are engaged, there are, nevertheless, in all occupations a gradual selection and elimination similar to those which occur in the schools. Persons with too low an intelligence for their occupation are unsuccessful and dissatisfied; and they are, therefore, eliminated. Those with more intelligence than is required eventually pass to better employment. Thus the average of the intelligence of the men in any particular employment affords a criterion of the degree of intelligence required in that occupation.

The preceding table is compiled from the results of the tests made in the army, and arranged in relation to the occupations of the men examined. The horizontal line after each occupation denotes the range of intelligence in reference to the rating on the abscissæ. The small vertical line crossing each horizontal, places the average of the group.

The results given in the table are based upon the army intelligence tests. It is not necessary or even desirable to apply such an elaborate test to determine the fitness of men for manual trades. Briefer and more comprehensive tests have been devised which not only judge the intelligence within the limits of those suited to the occupation, but which also take into consideration the physical attributes of coördination, eyesight, and health, and the mental attributes of initiative, alertness, and persistence.

Feeble-Mindedness.

Intelligence is inherited and not acquired or produced by education; the ancestry of the individual determines his mental endowment just as it does the color of his hair or eyes. Since the lower degrees of intelligence can be more accurately measured and graded than the higher, the relation between inheritance and intelligence has been worked out most fully in those persons who are classified as feeble-minded.

An individual is said to be feeble-minded when his intelligence fails to develop beyond that of the average child of twelve years. Within this range are found all degrees of feeble-mindedness. Those who fail to attain more intelligence than is shown by a

child of two years are classified as idiots; those who range from two through seven years are imbeciles; and those from eight to twelve are morons. Each group is subdivided into a low, middle, and high grade. Idiots are incapable of any occupation; imbeciles of the higher grade may do simple tasks, such as weeding a garden under supervision; the lower grade of morons are able to perform such tasks as scrubbing or mending, middle-grade morons make good workers at manual routine under supervision, and high-grade morons are capable of operating machinery or doing routine work without supervision.

In the discussion of the army alpha test no mention was made of rating by mental ages. The test was not designed for that end. It suffices here to state that the grade D— rates below a mentality of ten years. The Binet test was developed to judge the mental development of children, and has for the rating of each mental age the average shown by children of that age.

Feeble-Mindedness and Heredity.

The study of feeble-mindedness has led to the conclusion that the condition is determined largely by the Mendelian law of inheritance. The basis of this law was determined experimentally in 1866 by an Austrian monk, Gregor Mendel, although the significance of his observations was not realized until 1900. Mendel planted in his garden two kinds of peas, one tall and the other dwarf. He fertilized the tall variety with the pollen from the dwarf and the dwarf variety with the pollen from the tall. The seeds which developed were then planted. Tall peas grew from all of them. This crop was allowed to fertilize itself (the pea is self-pollenating) and these seeds in turn were planted. An unexpected growth appeared; there were both tall and dwarf peas, but there were three times as many tall as dwarf. Nor was this all, for when the seeds from this crop were planted only dwarf peas grew from the seed taken from dwarf plants, but from the seeds planted from the tall peas, providing they were unselected, there grew three times as many tall as dwarf, no matter how many years the tall ones were replanted. From among the tall ones a pure tall race could, however, be developed by selecting such as produced no dwarf offspring.

The explanation of the experimental findings of Mendel has become clear in the light of our present knowledge of reproduction. Both in animals and plants the "germ cells"—the ovum or egg from the female and the spermatozoon from the male—each contain a number of small bodies which, because they absorb certain dyes, are known as colored bodies or "chromosomes." Every species of plants and animals has a certain unvarying number of these bodies in its cells. During the maturing of the germ cells in preparation for union with the germ cells of the opposite sex, the number of chromosomes is reduced one-half. In the new individual formed by the union of the germ cells there is the regular number of chromosomes. One-half comes from each parent.

The chromosomes are considered to be the bearers of heredity. Each has within it certain particles which determine some quality or character of inheritance, such, for example, as the color of the hair. Certain of these characteristics take dominance over others and impart their quality whenever they are present in either of the germ cells which unite. The inheritance is not limited to the immediate parents of the individual, but extends back to the grandparents. The germ cells of the parent in maturing divide the chromosomes in half. These chromosomes contain the qualities from each of the grandparents, and if their characteristics have been different some germ cells during the division may receive the characteristics of one, while other germ cells may receive the characteristics of another grandparent. Any quality possessed by all the grandparents will, however, be found in all the germ cells after the division of the chromosomes. So far as can be determined the division of the chromosomes is controlled entirely by chance.

To return to the experiments of Mendel, the germ cells of the tall peas which he planted contained in their chromosomes a determinant for tallness. The seeds resulting from any combination in which this chromosome appeared grew tall peas. Therefore the seeds planted from the peas which were cross-pollenated all grew tall, for they contained half of the chromosomes from the dwarf and half the chromosomes from the tall peas.

When, however, these peas were allowed to pollenate them-

selves, the arrangement of the chromosomes fell into all the combinations of chance. There were four equal possibilities in this second generation. A seed might contain chromosomes derived entirely from the dwarf grandparent, and would, therefore, grow dwarf, or it might contain half from each grandparent in the two combinations possible, or it might have chromosomes derived entirely from the tall ancestors. Each of the last three combinations would grow tall peas, thus explaining the ratio of one dwarf to three tall found by Mendel.

Figure 49 illustrates the Mendelian law of inheritance as exemplified in the cross pollination of tall and dwarf peas. In this

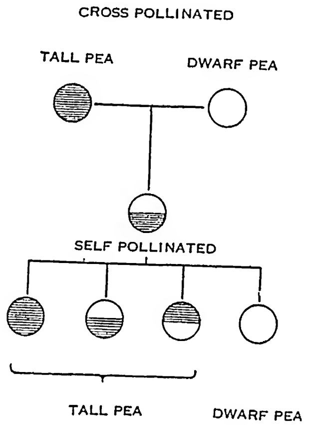
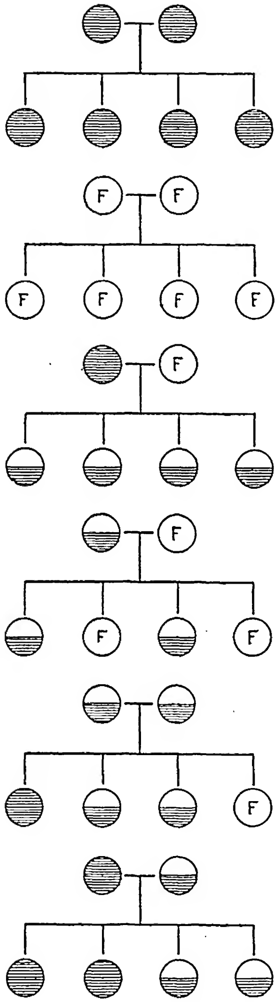


Figure 49. MENDELIAN LAW OF INHERITANCE ILLUSTRATED BY THE CROSS POLLINATION OF TALL AND DWARF PEAS.

figure the black represents the dominant quality of tallness while white is the recessive or dwarf quality. Any circle which contains the black represents the seed which will grow into a tall pea.

Feeble-mindedness is not a positive quality, but rather the condition which results when some quality, a degree of intelligence, is lacking. Intelligence is a dominant characteristic like the determinant of tallness in the peas in the experiments of Mendel. When the dominant quality of tallness is lacking in the seeds, dwarf peas result; when the dominant quality of intelligence is lacking in the germ cells from which the child develops, a dwarfed mentality results.

In considering the inheritance of feeble-mindednesss, or more



Mating of individuals who have received the dominant quality of intelligence from both parents, i.e., class 1.

All offspring normal minded; class 1.

Mating of feeble-minded individuals who have not received the dominant quality of intelligence from either parent, i.e., class 2.

All offspring feeble-minded; class 2.

Mating of individuals from class 1 and 2.

All offspring normal-minded but belonging to class 3.

Mating of individuals from class 3 and 2.

50 per cent of offspring feeble-minded and 50 per cent normal but of class 3.

Mating of individuals from class 3.

25 per cent of offspring feeble-minded. 75 per cent normal. But of these normals 66 per cent are in class 3. Only 25 per cent of all the offspring in class 1.

Mating of individuals from class 1 and 3.

All the offspring normal; 50 per cent in class 1 and 50 per cent in class 3.

Figure 50. INHERITANCE OF FEEBLE-MINDEDNESS ACCORDING TO THE MENDELIAN LAW.

correctly the failure to inherit intelligence, we must take into account three types of individuals: (1) The type composed of those who have received the dominant characteristic of intelligence from both parents. Such an individual may be represented by a black circle, like the tall pea which breeds true in the diagram of the Mendelian law. (2) The type of individual who has not received the dominant of intelligence from either parent and who is, therefore, feeble-minded. He is represented by the white circle. And (3) the type of individual who has received the dominant of intelligence from only one parent and who is represented by a circle half black and half white. He is not himself feeble-minded, for he has received the dominant quality; but he may have children who are.

Parents of these three types may breed in six possible combinations. The proportion of feeble-minded offspring may be foretold from the Mendelian law. This does not mean, however, that the laws of chance will operate with exactitude in the limited number of offspring which result from a single human mating. The nearly exact proportion will appear only when the children of many similar matings are taken collectively. Figure 50 shows the proportion of feeble-minded offspring from all the possible matings of parents of the three types.

Causes Other Than Heredity.

From Figure 50 it appears that children are not feeble-minded when they inherit from either parent the dominant characteristic of intelligence. Nevertheless, instances occasionally occur of a feeble-minded child from parents who are both in class I—i.e., both from families which have shown no trace of feeble-mindedness in previous generations. Therefore some factors other than inheritance may occasionally cause feeble-mindedness. An example of this is seen in the cretin, a person rendered feeble-minded through lack of the thyroid secretion, and consequently by an arrest of development. Again in rare instances the child may be injured by an illness of the mother before birth, or by an accident during birth or early childhood. Many cases of feeble-mindedness are popularly attributed to these accidental causes, but in most instances a study of the child's ancestry

shows that the real cause is inheritance. Meningitis in early childhood accounts for a small percentage of cases of feeble-mindedness. There is a still smaller percentage of cases of so-called "mongolian idiocy." This is a peculiar type of feeble-mindedness which occurs in families in which the ancestry can be shown to be free from all taint of feeble-mindedness. Mongolian idiocy is not inherited, and like cretinism appears to be caused by some arrest in development. The cause is unknown. The term mongolian is used because the faces of these persons show some resemblance to the Asiatic type of countenance, particularly the slant eyes. Unlike a cretin, the mongolian idiot is not a dwarf in stature and physical development.

Characteristics of the Feeble-Minded.

Although a man of forty years may show an intelligence which would be normal for a child of ten, it does not necessarily follow that the adult is directly comparable to the child. A normal child of ten can learn to do a great many things; there are also many things that he can learn but cannot accomplish because he is not physically able. This incapacity is not present in the feeble-minded adult, for he is physically mature. Therefore, the feeble-minded adult has a larger range of capability than the normal child. Also the adult has had a longer and wider experience than the child and has, therefore, learned empirically how to proceed in many situations which he could not reason out when he first encountered them. Thus in some aspects the feeble-minded adult gives, superficially at least, the impression of having a higher intelligence than that of a child of equal mental age. The normal child is not expected to set himself at work voluntarily, to keep himself at work, to show responsibility, or to use good judgment in meeting the emergencies which arise in connection with his work. These qualities are frequently expected in the feeble-minded because of his adult years and physical development. In fact, however, in these qualities he has no advantage over the boy of equal mental age, and he should be treated accordingly.

There are no sharp demarcations of characteristics which serve to differentiate a feeble-minded from a normal-minded adult. The division is made at the minimum degree of intelligence which

allows a man to function successfully in his environment. A man is thus normal-minded if he is sufficiently intelligent to earn his living and manage his own affairs; a man is feeble-minded if he has not enough intelligence to compete on equal terms with men of this normal level. The distinction between normal- and feeble-mindedness thus turns upon the complexity of the environment in which the man functions. An intelligence which is sufficient to allow a man to earn a living and manage his affairs in a passable manner in a small rural community is insufficient for the same man when he attempts to live in a city. Thus by merely changing his environment the man passes from being relatively normal-minded to being feeble-minded.

A small percentage of all men, the idiots and imbeciles, is of such low mentality as to be incapable of functioning independently in any civilized community. A much larger group, the morons, is capable of functioning in a simple environment. When the environment becomes even slightly complex, those of the moron class cease to behave normally; the abnormality usually takes the form of pauperism, crime, or prostitution. The great majority of criminals, paupers, and prostitutes who are in institutions are persons of feeble mind from environments which were too complex for their mentality.

The mental age which is chosen to differentiate the normal from the feeble-minded is an index of the complexity of civilization. Since society is steadily becoming more complex and urbanization more general, the level of requisite intelligence is rising and the proportion of those who are classified as feeble-minded is increasing.

The Problem of the Feeble-Minded.

Improvements cannot be made through reform of the feeble-minded individual, for intelligence cannot be developed in those who do not possess it. There seems to be no immediate possibility of society becoming less complex. The principle of division of wealth or of land offers no solution to the problem, for those of low intelligence have not the capability or desire to improve their condition, nor the initiative to take advantage of any oppor-

tunity offered. They cannot by any economic change be brought onto a par with those who are their superiors in intelligence.

For the problem of feeble-mindedness and the abnormalities of society to which this condition gives rise, the obvious solution is eugenics. Intelligence is an inherited quality, and we are now able to evaluate it and to predict the approximate mental equipment which will fall to the offspring of a human mating. In this connection it may be mentioned that the strain of feeble-mindedness is usually introduced into an intelligent family through the female side. Many of the qualities in the male which make him a desirable mate, his ability and earning capacity, are results of his intelligence. These qualities are not expected in the female, and a girl of subnormal intelligence may have the beauty and grace that lead quickly to matrimony. For matings in which both parents are feeble-minded more stringent measures than simple eugenics are needed, for with these people the prevention of marriage is not synonymous with the prevention of offspring. Segregation in institutions is essential for those of the lowest mentalities, while sterilization serves for those of somewhat higher level.

Insanity.

The higher cerebral centers are concerned with the association of ideas. The response of the centers to stimuli determines a man's behavior. The response made by normal men may vary under similar stimuli, but all fall within a range of variations constituting rational behavior. When the function of the cerebrum is disordered a man may make irrational responses to stimuli, or even respond to stimuli which arise wholly from the disordered condition of the brain. His conduct is irrational; such a man is said to be insane. A man may exhibit marked peculiarities in his behavior and not be insane. As a result of strong impressions arising from unusual circumstances to which he has been exposed, or from the repressing of strong desires, he may unconsciously develop these peculiarities. He may have mental compulsions which force him to do strange acts; he may even commit crimes or participate in unnatural sexual acts. His behavior is not, however, the result of a diseased cerebrum; it arises

from an unusual, but nevertheless logical, association of ideas in a cerebrum which is normal. Insanity is due to a disorder of the cerebrum, so that the associations it makes are not logical. Mental disturbances are as definite in their symptomatology as are some of the infectious fevers.

Insanity and feeble-mindedness are quite different. The intelligence of an insane man may indeed deteriorate until he becomes feeble-minded. The feeble-minded man, on the other hand, has failed to develop in intelligence; he has not deteriorated. The distinction is the same as that between two men dwarfed in stature, one because he failed to grow and the other because he has had his legs cut off.

In some forms of insanity the disorder in the cerebrum is evident from changes in its anatomical structure; areas of degeneration or sclerosis are found. In other forms of insanity no definite anatomical alterations are found in the cerebrum. In these cases the action of the brain cells is perverted as from impoverishment in the nutrition of the brain, or through the action upon it of some poison either arising from within the body, as from infection, or administered to it. The irrational behavior of the drunken man or the drug addict, and the delirium of the man with fever, are forms of temporary insanity. Mere shortage of oxygen produces, while it lasts, a greater or less degree of mental unbalance. If the influence affecting the action of the brain cells is continued for a long time, anatomical changes appear in the brain and the condition becomes permanent in some degree. The drunkard then develops a persistent alcoholic insanity. It is probable that the changes in the brain which result in insanity arise largely from the same causes as those which produce changes in other organs of the body—by disease, by poisoning from the absorption of toxic material from foci of infection, by drugs, and by the hardening of the arteries. Insanity can often be cured in its early stages; when structural changes in the brain have developed, the condition may sometimes be arrested, but complete recovery cannot take place.

It seems probable that no form of insanity is directly hereditary. Some forms of insanity are definitely due to infection and cannot be hereditary. Paresis, which results from syphilis of the

central nervous system, does not occur in all cases of syphilitic infection of the nervous system; but the predisposition to develop paresis from the infection may be inherited.

The behavior of the insane man is determined by the areas which are affected in his cerebrum. The abnormality may appear in his perception, in his emotions and imagination, in his process of reasoning and judgment, and in his volition. There may also be changes in his muscular activity and reflexes, thus showing that the motor and sensory areas of the brain and even of the cord are involved. The association of certain of the abnormalities is sufficiently constant to permit the classification of several types of insanity. The more common are the so-called toxic insanities, the senile or involutional insanities, dementia præcox, dementia paralytica, manic-depressive insanity, and paranoia.

Forms of Insanity.

The toxic insanities are caused by poisons. The drunken man and the man drugged with cocaine or morphine exhibit in their behavior the symptoms of acute toxic insanity. Many other poisons, including lead, produce similar effects. The delirium of fever may also be included as a form of toxic insanity; in this case the poison is formed within the body by the action of bacteria. The man with acute toxic insanity usually recovers rapidly when the poisonous substance is eliminated from his body, just as the drunken man sobers up and the man with fever recovers. If the absorption of the poison is habitual, permanent changes occur in the nervous tissue and the insanity remains even after the poison is stopped. The most common form of this type of toxic insanity arises from alcoholism. The man with chronic alcoholic insanity gradually deteriorates in intelligence, his capacity for work is diminished, and his memory is defective. His moral deterioration is particularly marked. He loses all affection for his family and has no interest in their welfare. His sense of responsibility disappears; he has the "drunkard's humor." He is offensively bullying to the weak, and disgustingly humble to the strong. His speech is thick or slurring, his gait unsteady, and his hand tremulous.

The senile or involutional insanities are probably due to changes

in the brain similar in character to those occurring in many other parts of the body as a result of age. The changes in the arteries lead to arteriosclerosis, and in the brain to the mental changes of senility and the senile insanities. Most very old men deteriorate mentally; we commonly say that they become childish. Their perception and apprehension are diminished, their memory for recent events is lessened, and their emotions become blunted. In exaggerated forms these changes constitute insanity. The man so afflicted is self-centered, frequently avaricious, and lacks affection for others. He is dogmatic and intolerant in his view. He may deteriorate morally and use obscene language or attempt to marry a young girl. He is unable to manage his financial affairs. He may be restless at night and wander about the house.

Sometimes involutional insanity takes the form of melancholia. The man or woman so afflicted is despondent and apprehensive; the patient has delusions of self-accusation in which he believes that he has wronged other persons. Although there is no basis for his belief, he nevertheless suffers acutely in his remorse for the fancied acts. He finds in everything about him signs which indicate his wickedness; the whistle of a train sounding in the distance makes him believe that he has wrecked the train with frightful loss of life. His conscience torments him, he confesses his imaginary crimes and wishes for punishment. He is likely to commit suicide unless carefully watched.

Dementia præcox is at the other extreme of life from the senile insanities; the majority of cases appear before the twenty-fifth year. There are several forms of the disease, but all have in common a gradual mental deterioration leading in many instances to dementia. In the most common form of dementia præcox the young man or woman loses the accustomed activity and energy, and becomes self-absorbed, shy, sullen, and seclusive, or perhaps irritable and obstinate. He is moody and indifferent to responsibilities. He may refuse employment and sit for long periods in self-absorption, or he may become restless and wander from place to place begging and committing small thefts, as a "tramp." In some cases the disease progresses no further; in other cases the man becomes childish, acts foolishly, and laughs in a silly manner without provocation. In one form of de-

mentia præcox, the catatonic, there are stages when the man becomes stuporous and must be fed by a stomach tube, or when he adopts a stereotyped movement and sits for days going through some purposeless act; or he may remain motionless in any position in which he is placed—catalepsy. In still another form of dementia præcox, the paranoid form, the mental deterioration is accompanied by fantastic delusions and even hallucinations of persecution. He believes the neighbors are conspiring against him, and that by means of wireless telegraphy they send derogatory messages into his room. The most insignificant occurrence, such as two people talking together, forms a basis for the persecution which he believes he is undergoing.

Dementia paralytica, or paresis, is due to syphilis of the brain. The man suffering from this disease fails in increasing degree to apprehend his surroundings. His consciousness becomes clouded; he lives a dreamy existence removed from realities. Eventually the mental deterioration progresses to a point where he is no longer able to perceive and react to any external impression. The unreality in his mental existence is indicated by delusions of grandeur in which he believes he has become a great financier and is vastly wealthy, or that he has developed some revolutionary invention, or that he has become divine. The destruction of the nervous system is also indicated by changes in the reflexes, similar to those in locomotor ataxia, and by loss of muscular coördination.

In manic-depressive insanity mental deterioration is less marked than in most forms of insanity. The man so afflicted exhibits a cycle of mental changes ranging from extreme alertness and activity to profound depression. In the maniacal phase the man responds to the most trivial excitation; he is incessantly active, excited, and exhilarated. He talks and laughs wildly. For days or even weeks he may continue his activity with almost no sleep. After the period of mania the symptoms may disappear for some time and he may appear nearly normal; or he may pass into the depressive phase of the disease. In this stage he is slow and uncertain in his movements and is depressed in all his emotions.

Paranoia is one of the less common forms of insanity. The

disease develops slowly and consists in the elaboration of a systematized delusion of persecution. The man so afflicted believes that he has enemies and is unjustly treated. The most trivial occurrences are interpreted by him in this light. Not infrequently the first striking evidence of the disease is a murderous assault on the person whom he believes to be causing the persecution. Another turns to law and follows a hopeless litigation from one court to another. The legal statutes appear to him inadequate; even the fundamental principles of the law fail in their comprehension of his case. He writes long and repetitious "crank" letters to magistrates, to the President, and even foreign rulers.

CHAPTER XVIII

POSTURE AND THE MECHANICS OF BONES AND JOINTS

ALL movements of the body are performed by the muscles, for they are the only structures of the body capable of liberating energy in the form of mechanical work. The muscles, when stimulated, shorten along their long axis and exert a pull upon the bones to which they are attached. Although power is furnished by the muscles, they alone are not sufficient to accomplish the intricate tasks to which this power is directed, tasks which include all the arts and handicrafts that man has invented. For this purpose a system for transmitting the power is as necessary as the power itself. This system is supplied by the bones to which the muscles are attached. The bones, moving about the joints, act as levers for the transmission of the power of the muscles, and make possible the application of the power in a great variety of acts.

The Skeleton.

The bones are the only rigid structures in the body. They furnish the framework which supports the other tissues. Deprived of bones, the human body would become a shapeless, flabby mass incapable of useful motility. In the body there are approximately 200 bones of various sizes and shapes. These bones are arranged in definite relation to one another; the complete structure thus formed is known as the skeleton. Where support is the main requisite in the skeleton, the bones are bound firmly together as in the spine; when greater motion is needed, the connection is more freely movable, as between the bones of the arm.

The characteristic shape of the human body is given to it by the skeleton. The spine, or backbone, made up of a series of disk-like bones firmly bound together, connects two girdles or rings of bone. One of these, the pelvis, or hip girdle, is a ring of massive bones attaching to the spine near its lower end. The bones of the leg are attached by joints, articulated, to the sides of this ring.

A less complete and less massive girdle, is supported near the upper end of the spine, and the bones of the arms are articulated to it. The short extension of the spine below the pelvic girdle is of little importance in man, but in many animals it is elongated to form a tail, a structure which man has, but which does not extend beyond his surface. The extension of the spine above the upper girdle bears at its top the skull. This last structure is a rounded, bony case containing and protecting the brain. To the skull is articulated the arched jawbone. The ribs form a series of arches between the upper part of the spine and the breastbone.

Development and Structure of Bones.

Development of the bones in the embryo is preceded by a deposit of connective tissue in areas which the bones are to occupy subsequently. This connective tissue is then converted into bone. The conversion commences as an irregular deposit of lime about the cells. These spicules of bone radiate in all directions from the centers of formation. At the same time, the outer layer of the connective tissue condenses to form a stout membrane, called periosteum, which is not converted into bone, but which persists as a covering for the bone. Beneath the periosteum a particularly dense layer of bone is deposited. Flat bones, such as those of the skull, when completely formed, consist of two layers of dense bone inclosing and united by a middle layer of spongy bone. The dense outer layers are covered with periosteum, and the interstices of the spongy middle layer are filled with red marrow. The general structure of the long cylindrical bones of the legs and arms is similar to that of the flat bones. The bone formation, however, occurs independently in the central part or shaft, and in the two heads or ends of the bone. The spongy central mass gradually disappears from the shaft, and a cavity is left which is filled with fat. The spongy formation persists in the heads; the irregular partitions of bone run parallel to the direction of greatest stress, forming a series of reinforcing arches.

Each head of a long bone is at first separated from the shaft by a layer of cartilage called the epiphysis—a provision which makes possible a great longitudinal growth of the shaft during the first few years of life. This growth is accomplished by the

transformation of epiphyseal cartilage into bone; at the same time the cartilage grows and maintains its regular thickness. When the bone has reached the requisite length, the cartilage ceases to increase in substance; it is converted into bone, and the heads and shaft unite as one complete structure. In the leg bones the union of the heads and shafts does not take place until about the eighteenth or twentieth year. The lateral growth of the shafts of the long bones is accomplished by the deposit of layers of dense

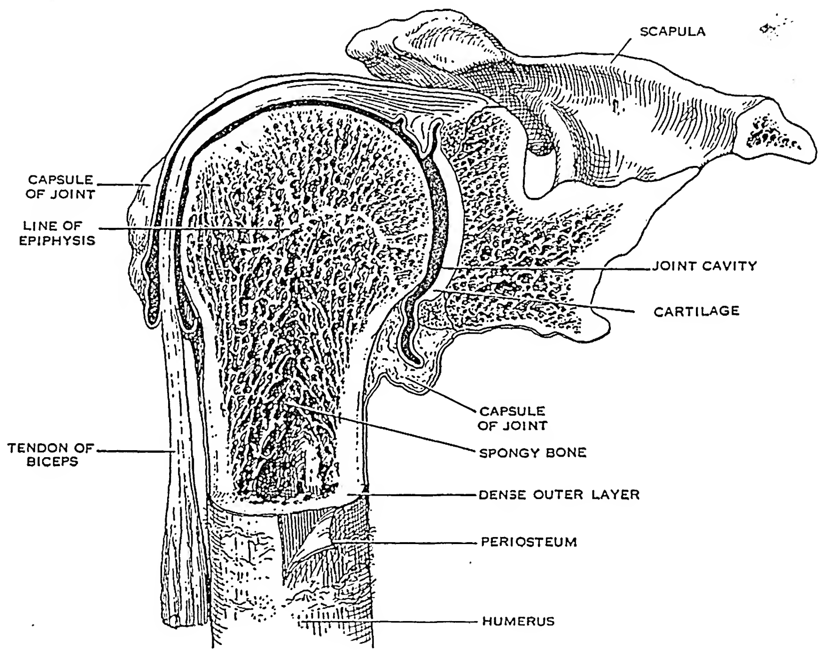


Figure 51. Section of Shoulder Joint.

bone on the outer wall beneath the periosteum. At the same time the spongy layers and part of the inner wall are absorbed. The shafts while increasing in diameter do not increase proportionately in weight. The pipe-like form of the long bones furnishes a much stronger structure than would a solid shaft of the same weight.

Defects of Development.

The shape and stature of the body are largely determined by the bones; abnormal and incomplete development results in de-

formity. The internal secretion of the pituitary gland exercises an influence upon the development of the bones; overactivity of this gland leads to gigantism or to acromegaly, while underactivity leads to dwarfism (see Chapter XXIII). The disease rickets interferes with the growth of the bones, and is a common cause of their abnormal shape. The distortion of the pelvis by rickets interferes with the bearing of children (see Chapter XXII). In rare instances, from some unknown cause, the epiphyseal cartilage between the head and shaft of the long bones fails to undergo conversion into bone, and in consequence these bones fail to grow in length. A type of dwarfism results. These dwarfs do not have symmetrically formed bodies as do dwarfs resulting from an insufficient secretion of the pituitary gland. Instead, their trunk is of normal size, but their legs and arms are short and bent. Their face is usually small and the bridge of the nose depressed.

Numerous defects occur in the bones in consequence of localized arrest in their development after birth. The cleft, or dimple, in the chin is one of the commonest of these defects. The lower jaw develops in two halves which at birth are joined in the center by connective tissue. Incomplete ossification of this connective tissue results in a depression in the chin. A similar developmental defect in the bones of the upper jaw results in the more serious harelip or cleft palate. The upper jaw and roof of the mouth are developed from a central and two lateral sections. Failure of the lateral and central sections to unite at the front of the jaw results in harelip. The name is derived from a somewhat analogous condition occurring in the hare or rabbit. Failure of the sections in the roof of the mouth to unite leaves an opening from the mouth into the nasal passages, cleft palate. Both harelip and cleft palate can be corrected in infancy by surgical operation.

Inflammation of Bones.

Inflammation occurs in bones just as it does in any other tissue of the body; it is called osteitis. When the central cavity of a long bone is particularly affected, the name osteomyelitis is usually substituted. Three different types of changes occur in bones as

a result of inflammation: (1) In rapid inflammation an area of the bone dies, and is separated from the living bone. The dead portion then becomes a foreign body in the flesh, and must usually be removed by surgical operation. (2) In less acute inflammation, and also in that resulting from tuberculosis, the affected bone is destroyed, becoming soft and porous. This process of destruction is known as caries. Decay of the teeth, or dental caries, for example, often leads to a localized destruction or caries of the jawbone. (3) Chronic inflammation, or the healing of an inflammation, leads to a thickening and hardening of the bones. Certain inflammations in the joints, called rheumatoid arthritis, lead to thickening of the bones near the joints, and cause deformity, particularly in the fingers.

Inflammation of the bones may occasionally arise from a blow over the bone without the introduction of bacteria. More often it results from infection. This infection may arise from direct contamination, as in a compounded fracture, or indirectly from bacteria carried by the blood to the bones. Tubercular infection of the bones is particularly important because it is the common cause of hunchback and hip-joint disease. Tuberculosis of the bones occurs most often in children. The bones of the spine, of the knee, and of the hip are affected commonly. The caries caused by tuberculosis results in a slow destruction of the bone. When the spine is affected, the bodies of the vertebræ are softened, the pressure from the weight of the body causes them to fall together and produces a backward displacement of the spine which in its extreme form is popularly known as hunchback. After the disease has lasted from one to three years the inflammation usually ceases and repair begins. The diseased vertebræ knit together into a solid mass. The deformity caused by the disease can be limited, and in many cases avoided, by the wearing of a properly designed support, until repair of the bone takes place.

Tubercular disease of the hip, like that of the spine, gives little immediate indication of its development. If detected in its early stages the disease can often be cured without leaving any deformity. If allowed to progress, the disease extends into the hip-joint and destroys the head of the femur. This bone then grows firmly to the pelvis, so that deformity and permanent lameness result.

Inflammatory changes in the bones sometimes extend throughout the skeleton. In chronic phosphorus poisoning all of the bones are rendered fragile. A similar change of unknown cause occasionally affects women during pregnancy and lactation, perhaps from insufficient calcium in the food. The bones may become so fragile that they bend or break under the weight of the body. In the disease osteitis deformans, the bones become not only softened, but also increase in size. This disease usually attacks middle-aged men. Its course is slow; as the bones bend out of shape, the body appears to be broadened and shortened; the shoulders are hunched forward and the legs bowed.

Fracture of Bones.

The breaking of a bone usually results from some sudden external force applied to the bone. Thus a blow struck over the leg or jaw may fracture the bone. The fracture does not always occur at the place where the force is applied. In jumping from a height the force of landing is applied at the feet but the fracture may occur in the upper part of the legs. The bones of the legs are compressed by the force, and yield at the weakest point; the direction of the fracture is determined by the direction of the stress. Fractures may also occur from the pull of the muscles during violent effort, as in the sudden jerk made to prevent a fall. Such fractures are usually in small bones or at the prominences of bones to which muscles are attached.

The bones of some people break with unusual ease; in some cases as a result of the ordinary movements, the so-called spontaneous fracture. A case has been reported of a girl, aged thirteen, who suffered from forty-one fractures. More often the fragility of the bones is due to some disease, either of the entire skeleton or in one of the bones. The bones of the aged are more brittle than those of the young, and break more easily.

Usually a fracture is across the bone. In children, however, a bone sometimes breaks only part of the way across, and at the same time bends and splits longitudinally; this is called "green-stick fracture." Similar incomplete fractures occur in the bones of the skull. On the other hand, when a great force is applied to a bone it may be shattered into small bits—that is, "com-

minuted." One end of the broken bone is sometimes pushed through the skin by the force causing the fracture, as in jumping from a height. Such a fracture is said to be "compounded." It is unfortunate, but often the case, that misdirected first-aid administration results in compounding a fracture. As a rule, a compound fracture is much more serious than a simple fracture, both by reason of the hemorrhage which may result and from the infection of the projecting bone by contamination with dirt. In fact, it was the observation of the frequent suppuration about the bones in compound fractures, and the absence of this complication in fractures which were not compounded, that led Lister to the doctrine of antisepsis which he introduced into surgery.

At the time a fracture occurs the person usually feels or hears something give way with a snap. At the same time pain occurs, and becomes more severe if movement is attempted. The area surrounding the fracture swells, and often the skin appears red and blotchy. Partial or complete loss of function of the part usually occurs. Movement may be accompanied by a grating sensation as the broken parts rub over each other. The abnormal posture into which a broken limb is forced is sometimes a definite indication of a break; the limb may bend at the point of the break. The examination to determine whether a bone is broken should be carried out with great caution, both because of the pain it causes and because the fragments of the bone may be moved from their position, or even forced through the skin and thus compound the fracture. The final determination, and in many cases the only possible determination, of a fracture is made by X-ray examination. Such examination should be made in every case of suspected fracture.

Fractured bones usually knit together when the broken ends are held in apposition. The setting or "reduction of the fracture" should be performed by a physician, for it must be done skillfully in order to avoid deformity. Sometimes reduction can be effected only by surgical operation. After the fragments are brought into the proper position they are held in place by a splint. A splint is a support of rigid material, wood, metal or plaster, fitted over the limb and extending above and below the

fracture. The setting of a broken limb can be greatly facilitated by proper first-aid treatment. This treatment consists of securing the limb in a rigid position with the minimum of preliminary movement. For this purpose a temporary splint is made from any convenient stick, and to this the limb is strapped or tied, but not so firmly as to impede the circulation. A broken leg may be held in position by tying it to the opposite leg. In performing first-aid work the subject should never be carried by lifting him at the shoulders and feet until it is certain that the legs are not broken for otherwise a fracture may be compounded during the lifting.

Fracture of the skull deserves special mention both because of its seriousness and because it is often overlooked at first. A violent blow applied to the skull fractures and depresses the bone; a less violent blow may lead to a crack in the bone which does not at once indicate its presence; nevertheless, it is extremely serious. A fracture of the skull may be produced in other ways. When a man falls from a height and lands on the feet, the upper end of the spine may be driven against the skull with sufficient force to crack it. Every case in which there is the slightest suspicion of fracture of the skull should be taken to a hospital for observation. Unconsciousness does not always occur in fracture of the skull, and the subject may be in apparent good health for several days after the fracture. Hemorrhage from the mouth or ears after a fall or blow is a serious symptom, for it is suggestive of a fracture of the skull, as is also blackening of the lower lids of both eyes. The bleeding in these cases occurs through a crack at the base of the skull. Hemorrhage into the skull increases the pressure there. The bones of the skull cannot yield, and the brain is compressed. Death may result if the pressure is not relieved and space allowed for the swelling, by a surgical operation called trephining, in which a hole is cut in the skull.

Fracture of the spine differs from other fractures for the reason that the spinal cord runs through a cavity in the vertebræ which make up the spine. Displacement or bending at the fracture brings pressure upon the cord, and causes paralysis and often death. Such fractures are difficult to treat, and in many in-

stances do not knit, although in occasional cases complete recovery results.

Joints.

The attachment, or "articulation," of one bone of the skeleton to another is called a joint. In some of the joints the bones are locked as one piece and no movement can occur at the union: such is the case with the bones of the skull, which are dovetailed rigidly together. In other joints the bones are bound together firmly with fibrous connective tissue, and only slight movement is possible between them; such are the joints between the pelvis and the spine. Other joints, such as those of the knee, elbow, and jaw, have a specialized structure which permits free movement. The ends of the two bones, meeting at a freely movable joint, are expanded and conform more or less exactly to one another in shape. That is, if the head of one bone is shaped like a ball the other is hollowed out to form a socket. At these surfaces the bones are particularly dense and strong. Layers of cartilage cover the opposing ends of the two bones, and the cartilages are covered with a thin "synovial" membrane which forms the friction surfaces of the joint. (See Figure 51.)

Ligaments bind the bones together at the joint and prevent their separation or displacement. These ligaments form a sheath or capsule about the joint. This capsule is inelastic but pliant, and sufficiently loose to allow movement. The muscles attached to the bones on each side of the joint assist in holding the bones in apposition; if a pull is made on the bones sufficient to overcome the tension of the muscles, the articular surfaces of the bones can be separated a short distance.

The capsules about the joints are lined with synovial membrane, which is a continuation of that covering the cartilage of the ends of the bones. The synovial membrane thus forms a sac within the joint. This membrane secretes a viscous fluid called synovia, which resembles white of egg and which lubricates the joint. A capsule similar in structure to that of the joints, and likewise lined with synovial membrane, surrounds long tendons, such as those to the fingers, forming a lubricated sheath through which the tendon slides. Small closed sacs lined with synovial

membrane also occur about some of the joints and over bony prominences where pressure is frequently applied. These sacs, or "bursæ," normally give some protection to the joints. When they are pressed upon to an unusual extent, as in certain occupations, they become inflamed and fill with fluid, or even pus. Swellings are formed which are sometimes painful. The condition produced is often named after the occupation in which it occurs, such as, for example, "house-maids' knee," in which the bursa of the knee is inflamed, or "miners' elbow," when the bursa of the elbow is swollen.

Sprains.

Sudden stretching of the ligaments of the joints, such as occurs when the weight of the body comes down upon the foot with the ankle turned sideways, results in stretching and tearing the synovial membrane, and may even pull the capsule from its attachment to the bones. Sprain, as this condition is called, is associated with severe pain, and is immediately followed by hemorrhage into the tissues about the joint. The area is colored bluish by the blood as in a bruise. Fluid also seeps from the blood vessels and collects in the tissues, causing swelling. A severe sprain requires a long period of rest, followed by massage and thermal treatment, before the joint is restored to normal condition. A neglected sprain may lead to permanent weakness and chronic pain in the joint affected.

Dislocations.

Displacement of the bearing surfaces of the joint from their normal relation is called dislocation. Dislocations are usually caused by external force, but occasionally also by the pull of muscles. A bone which is dislocated is held in its abnormal position by the pull of the muscles attached to it. Frequently the capsule about the joint is torn, the bone passes through the opening, and slips entirely away from the normal bearing surface.

The treatment of a dislocation consists in restoring the bones to their normal relations, and supporting them in place until the injury to the capsule has healed. This setting, or "reduction," of a dislocation is best effected by moving the joint in such direc-

tions as to cause the end of the bone to retrace its course and slip back to its normal position. Reduction by this method is most easily applied to the shoulder joint. When reduction cannot be effected by manipulation, it is then necessary to overcome the muscles by force and pull the bones into place. This procedure is readily applied to dislocation of the fingers and of the jaw, but for larger joints should be performed by a physician, and usually under anesthesia. Considerable damage to the joint may result from misdirected and overzealous efforts at reduction by force during first-aid procedures. If the ligaments of any joint are permanently stretched by disease or repeated dislocation, the condition is commonly referred to as "double-jointedness."

Dislocation of the vertebræ of the spine is a very grave condition for the same reason as that given for fracture of the spine. Simple dislocation of the spine occurs only in the neck region, for the vertebræ in the remainder of the spine are cupped into one another in such a manner that dislocation can occur only when the bone is fractured. Dislocation of the spine in the neck may result from blows and also in hanging; in fact, the purpose of the "drop" in hanging is to accomplish the dislocation of the vertebræ and to produce immediate death from compression of the cord, rather than to allow death to take place by strangulation.

Infections of the Joints.

Inflammation or infection of the joints is known as arthritis. The infection results from the introduction of bacteria, either through a wound into the joint, or from an extension of infection from other parts of the body. In acute infections the joints swell and pus is formed in the cavity lined with synovial membrane. Such infections are serious because during the healing process the inflamed membrane and cartilages may grow together, and subsequently be turned to bone, thus knitting the bones together at the joint and abolishing motility. Occasionally a chronic inflammation of nonbacterial origin occurs in many joints and is followed by union of the bones, causing the entire body to become rigid, until the only motion left is perhaps a slight movement of the fingers and the jaws. The "petrified man" of the

circus side show is an example of this disease; most of the other exhibits in such places suffer from disturbance of the glands of internal secretion.

Inflammation of the joints may occur without the formation of pus, as in acute articular rheumatism, or may even arise without infection. The latter type of inflammation generally occurs as the result of injury or cold. The inflammation is centered particularly in the synovial membrane lining the capsule. Swelling results from the collection of fluid in the space of the joint, so-called "water on the joint." After passing through the acute stages, the inflammation usually subsides. The joint may have developed some limitation of movement, and may give a slightly grating sound when moved. A similar type of inflammation occurring in the sheath about the tendons is called a "weeping tendon."

Mechanics of Bodily Equilibrium.

The body is of irregular shape and density. Its center of gravity, as in any other system of masses, is represented by a

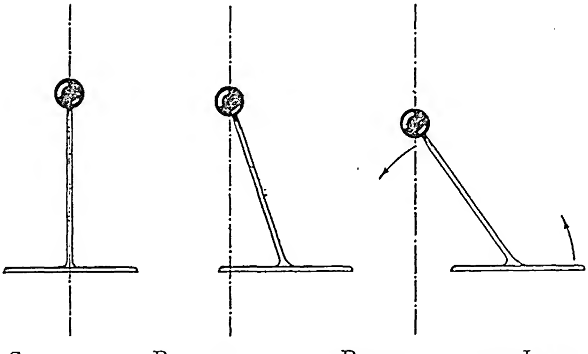


Figure 52. STABILITY IN RELATION TO THE POSITION OF THE LINE OF GRAVITY.

point so located that gravity appears to act entirely upon that point. The center of gravity may or may not be within the substance of the body. When the human body is extended rigidly and laid flat upon a board, and the board is adjusted at various points across a sharp edge, a position is found at which a balance is obtained, as in the seesaw used by children. In that particular position the force of gravity appears to act upon the body in only

one place, a point directly over the sharp edge upon which the board rests. That point is the center of gravity of the body.

In the erect position the center of gravity of the body is at about the level of the navel. In this position the body is supported by a base formed by the feet and the area between them. Treating the human body as a rigid system, which it is not, it can be represented in its relations to gravity by a mass equal in weight to the body and supported by a line attached to a base, as is shown in Figure 52.

The dotted line in this figure represents the direction of the force of gravity. The mass supported will remain stationary in any position in which the line of force passes through the base. In the third diagram the line of force falls outside of the base and the mass will therefore fall over. The stability of the mass depends upon three factors: (1) the height at which it is supported above the base; the shorter this support the greater the stability; (2) the area of the base of support; the larger the base the greater the stability; and (3) the point at which the line of gravity cuts the base; the nearer the center the greater the stability.

In distinction to this rigid system the body is segmented in structure and is flexible. In order to maintain a state of equilibrium in the erect position muscular force must be exerted internally to afford sufficient rigidity in its various parts to hold the center of gravity over the base. An unconscious man or a drunken man cannot stand, because the muscles fail to hold his body sufficiently rigid. The more stable the system, the less will be the muscular force necessary to maintain the upright position.

The Erect Position.

There are three ordinary standing positions: that of "attention," that of "at ease," and the "hunched" attitude. These three positions are illustrated in Figure 53. In both of the symmetrical positions the weight of the body is equally distributed between the two legs. In the position of attention the line extending from the center of gravity to the base formed by the feet passes to the

rear of the center of the base and hence outside of the position of maximum stability. In the attitude of "at ease" the body is more stable, for the line passes through the center of the base. In the asymmetrical or "hunched" attitude the weight of the body is carried largely on one leg; the other by being put to one side makes a wide base and hence effects a greater stability even

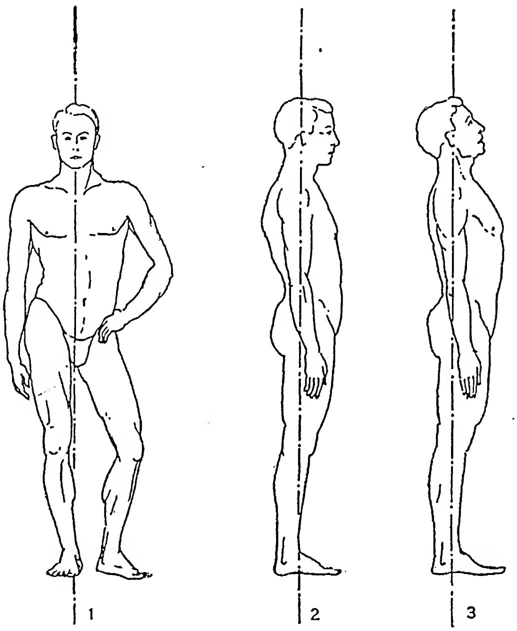


Figure 53. Positions in Standing.
(1) Hunched.
(2) At ease.
(3) At attention.

though the line of gravity falls nearer to one side of the base. Standing with the legs spread wide apart in like manner increases stability.

The degree of stability given by any erect position is reflected in the muscular energy necessary to maintain the position. The relative amounts of energy expended in sitting and in standing in the three positions described are given in the following table. The figures are estimated on the basis of 100 per cent as the energy expended during sitting.

	Relative Energy Expended (approximate)
Lying	92
Sitting	100
Standing "hunched"	103
" "at ease"	106
" "at attention"	125

In movements of the body with the feet stationary, as in bending forward or backward, various segments of the body are

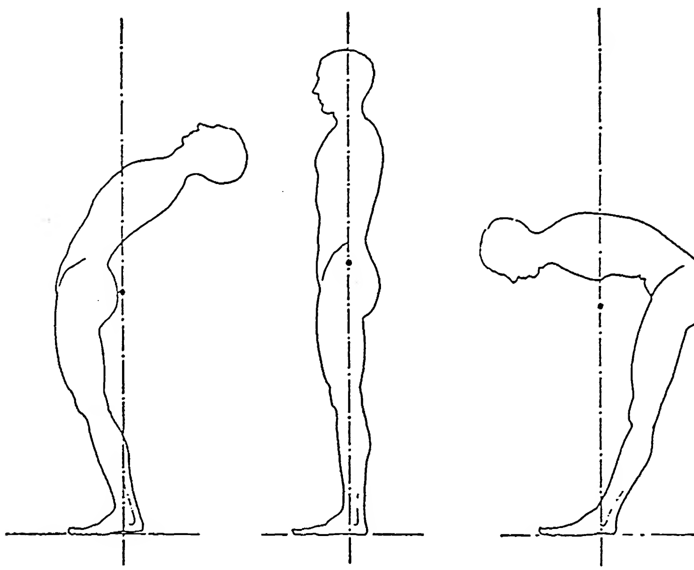


Figure 54. Change of Center of Gravity with Movement of the Body.

moved to compensate for the displacement of mass, so as to keep the center of gravity over the base. Figure 54 illustrates this principle.

Any burden carried by a man becomes part of the system acted upon by gravity. The center of gravity is shifted and the position of the body is altered to bring the center over the base. A man carrying a burden in one hand leans to the opposite side and even extends the free arm for further compensation. A burden borne on the back is compensated for by bending forward. Similarly, alterations in the distribution of the mass of

the body involve change in position. In pregnancy the shoulders are thrown back to counterbalance the weight of the uterus; a similar change is seen in obese men. The hunchback must stand so as to support his center of gravity; the man bent with age has recourse to a stick in order to increase the area of his base of support.

Position is maintained by coördinated muscular activity. The muscles applying the internal forces which hold the body rigid are maintained at a steady pull. Slight displacements of the body are compensated unconsciously by changes in the tenseness of the muscles. If the body is forced far from its position it is brought back to equilibrium without conscious effort. The coördination of muscular activity through which equilibrium is maintained is effected through the nervous system under the influence of impulses which arise from vision, from the vestibular portion of the inner ear, and from the joints, muscles, and tendons. Any two of these systems may be sufficient to supply the necessary impulses to the nervous system, but at least two are necessary. The normal man can stand erect and maintain his equilibrium with his eyes shut, but the man with locomotor ataxia cannot, for, as a result of his disease, impulses are not carried to the nervous system from the muscles, joints, and tendons of his legs, so that it is necessary for him to use vision to maintain equilibrium.

If a man stands stiffly in position of attention he soon becomes fatigued. Although the energy expenditure required to maintain the body rigid is not great, it is nevertheless carried out by a group of muscles acting at a great mechanical disadvantage. These muscles are, considering their mass, making a large and sustained exertion and rapidly become fatigued. Moreover, the erect position is disadvantageous for the return of the blood through the veins of the leg, a topic discussed under varicose veins. The heart pumps less blood, when the body is held erect and stationary, than it does in the sitting and lying positions, or during even moderate movement of the body in the erect position. It is not uncommon for soldiers to faint after standing for some time in the position of attention.

Posture.

The posture assumed in both sitting and standing is not only a matter of esthetics, but is also of great practical importance for health and efficiency. Improper posture increases fatigue. It is also the main cause of a number of ailments; the most common are back strain and pain in the muscles of the back. It may also lead to disturbances in the function of the alimentary and urinary systems. Correct posture depends upon the manner in which the spine is held, and a consideration of the anatomy and physiology of this region is essential to a discussion of posture.

The Spine.

The spine is composed of a series of thirty-three or thirty-four bones shaped like disks. These bones are called vertebræ, and are piled one upon another. The space between adjacent

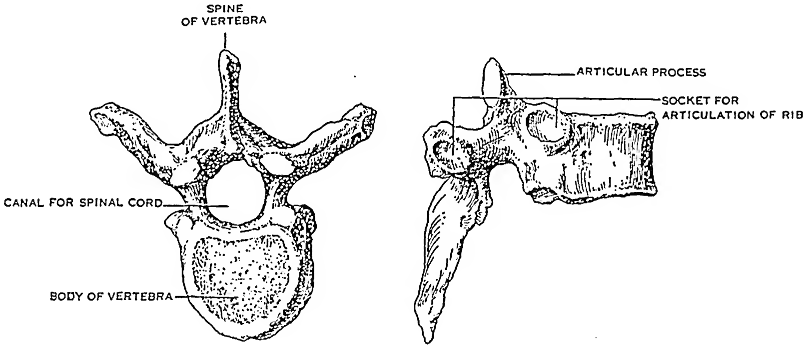


Figure 55. Vertebra, Top and Side View.

bones of the column is separated by a disk of cartilage and surrounded by a capsule of ligaments, so that a joint is formed between each two vertebræ. The column of vertebræ is held in position by muscles, the loin muscles, which run up the sides of the vertebræ and are attached to them. In addition to the muscles, a series of ligaments run lengthwise of the spine and are attached to the sides of the vertebræ. These ligaments restrain the movement of the spine within certain limits. The ill effects of improper posture result in part from the strain put upon these ligaments. The extreme limit of movement of the joints of the

vertebræ is fixed by processes of bone which extend from the rear of the body of the vertebræ and come in contact with similar processes of the adjacent vertebræ. The spinal column of

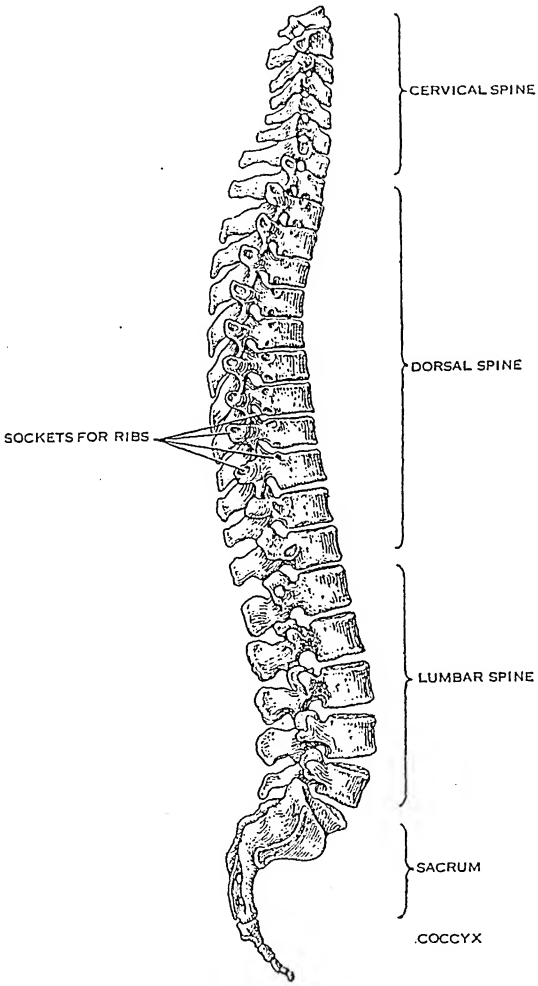


Figure 56. THE SPINE.

different animals has various degrees of flexibility. That of the cat is particularly flexible.

For purposes of description the spine is divided into four segments. That portion extending through the neck is known as the cervical spine. Its vertebræ have the freest motion. The

portion of the spine which runs behind the chest is called the dorsal spine. The lateral motion of the vertebræ has there an additional limitation because of the attachment of the ribs, but rotation is not interfered with. The portion of the spine extending from the lowest rib to the top of the pelvis is called the lumbar spine. The vertebræ in this region are so constructed that bending is possible, but rotation is very limited. The vertebræ below the lumbar region are fused together into one piece called the sacrum.

The bones of the pelvis are jointed to the sides of the sacrum. The pelvic bones form an arch with the junction of the two bones in the mid-line of the body at the lowest part of the abdomen. The sides of the pelvic bones are flared outward at the top to form the hips, while below this projection are sockets to which are articulated the bones of the legs. The sacrum resembles a keystone in the arch formed by the pelvic bones, but it is an inverted keystone, for it is narrower at the outside than at the inside. The weight of the body in the upright position tends to force the sacrum into the pelvic opening. This force is counteracted by ligaments which tie together the sacrum and pelvic bones, and prevent almost all motion in this joint. The burden placed upon the ligaments connecting the pelvis and sacrum is great; not only must they bear the inward thrust of the sacrum due to the weight of the body, but they must also counteract the tendency of the pelvis to rotate upon the sacrum. The bones of the leg push up on the pelvis at a point in front of the spine; their force tends to lift the front of the pelvis and rotate it. The pelvis is considered in its relation to childbirth in Chapter XXII, and is shown in Figure 72.

Curves of the Spine.

The spine normally has four curves. In relation to the front of the body they are a convexity in the cervical region, a concavity in the dorsal, a convexity in the lumbar, and a concavity in the sacral. The curves in the dorsal and pelvic regions are in comparatively rigid portions of the spine and are present at birth, but at this time the remainder of the spine is straight. The curvature in the neck appears only when the child begins to hold

the head upright; the curve in the lumbar region develops only when the upright position is assumed. These curvatures are thus secondary to position and tend to compensate for the inclination of the pelvis and the curvature of the dorsal region. It is these secondary curvatures which are at fault in improper posture; the primary or fixed curvatures are not then properly balanced, and a strain is put upon the ligaments and muscles of the spine. Excessive curvature of the lumbar region may displace abdominal viscera.

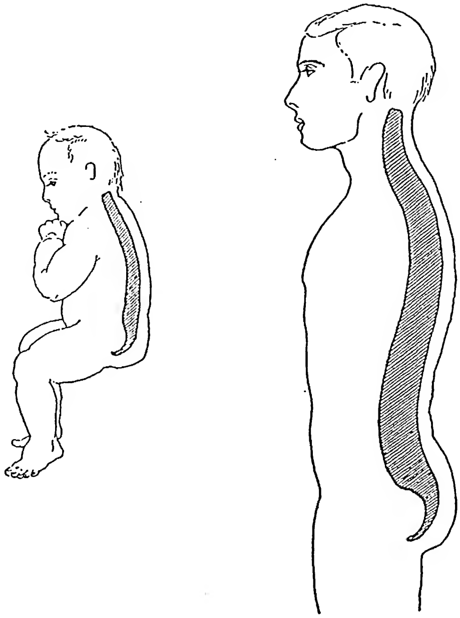


Figure 57. DEVELOPMENT OF THE SECONDARY CURVES OF THE SPINE.
The spine of the infant shows only the two primary curves; the spine of the adult shows, in addition, the secondary or compensating curves due to the erect posture.

The balanced relations of the curves of the spine are so accurate that no one curve can be increased or decreased without a corresponding increase or decrease of the others. With every movement of the body the center of gravity shifts, and compensatory changes in the curvature of the spine must occur in order to maintain balance. In the proper standing or sitting positions all of the curves are slight, and none of the spinal joints

are used to their limit of motion. The load is evenly distributed to all of the supporting muscles, so that there is no excessive fatigue and the ligaments are protected from strain.

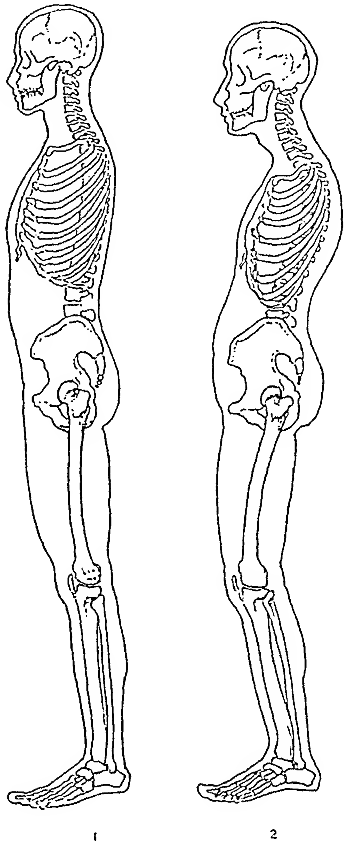


Figure 58. Position of Skeleton in Good and Bad Standing Postures.

(1) Good posture; line of gravity follows main line of bony structure, and bones carry the weight.

(2) Bad posture; a burden is thrown on the muscles and ligaments because of the exaggerated curves of the spine.

Incorrect Posture.

In incorrect posture the curvatures of the spine are exaggerated, and the joints of the spine are used to the limit of their motion. The ligaments which normally check extreme ranges of motion are constantly under tension. Moreover, the muscles no longer carry an evenly divided burden. Those which are overworked

become rapidly fatigued; the burden placed upon the ligaments strains these structures. The skeleton possesses great resources for compensation to improper posture, so that this condition may be borne for a long time without demonstrable damage. The

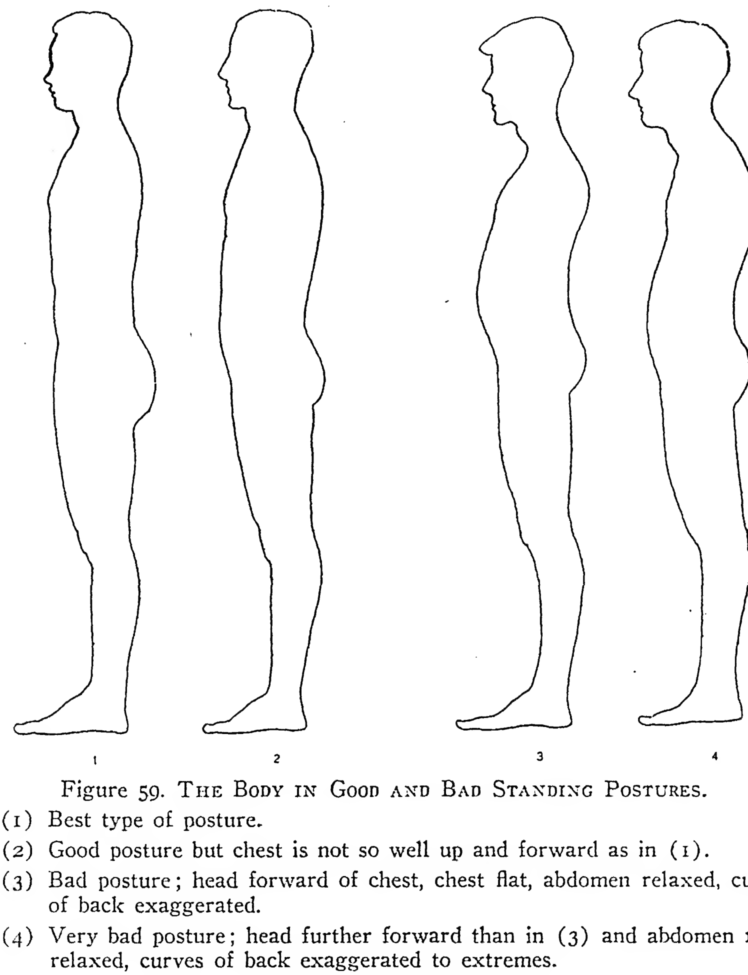


Figure 59. THE BODY IN GOOD AND BAD STANDING POSTURES.

(1) Best type of posture.

(2) Good posture but chest is not so well up and forward as in (1).

(3) Bad posture; head forward of chest, chest flat, abdomen relaxed, curves of back exaggerated.

(4) Very bad posture; head further forward than in (3) and abdomen more relaxed, curves of back exaggerated to extremes.

A large majority of men stand as in (3) or (4).

ability to compensate varies with each individual, and seems to depend upon the difference in construction of the skeleton.

Figure 58-1 shows the normal skeleton in proper standing posture. Figure 58-2 shows the skeleton in improper standing posture. In proper posture the line of gravity follows the main

line of the vertical bony structure, and the bones carry more of the weight than in the second figure, where the burden is thrown upon the muscles and ligaments.

Figure 59 shows the body in silhouette in typical standing postures. It is in the postures shown as 3 and 4 that the ailments common to improper posture occur, backache, lumbago, legache, and disturbances in the digestive and urinary functions. It does not follow that incorrect position is inevitably accompanied by symptoms. Violation of the principles of correct body mechanics predisposes to them; slight injury, extreme fatigue, or illness may furnish the additional aggravating factor necessary to produce the acute effects.

The relationship between health and posture is two-sided: ill health and fatigue cause improper posture; improper posture causes ill health and fatigue. It is possible to correct posture by working from two sides; the health must be improved and the proper body mechanics assisted. In working conditions the former means fresh air and good light and rest periods, together with instruction in proper living. Development of normal body mechanics is assisted by prevention, so far as possible, of improper posture, by provision of suitable seating, and by arrangement of work so that it is not necessary for the worker to assume abnormal positions.

Principles of Correct Seating.

Many workers in stores, offices, and factories spend nearly a third of the twenty-four hours in a chair. The shape of the chair contributes greatly to the maintenance of correct posture, and thus indirectly to the prevention of fatigue and the development of proper bodily mechanics. Anyone can demonstrate to himself the point at which support is needed in the sitting position by sitting erect and then gradually relaxing, allowing the back to bend naturally. It will be found that the middle of the back bulges directly backward. Support for the back at this point is important in maintaining correct posture. This support is not furnished by the ordinary chair, which supplies a rest only for the shoulders. Moreover, for the back support to be effective, the

seat of the chair must be narrow from front to back, approximately one foot. The shallow seat brings the occupant to the back of the chair, which should be bowed forward slightly to meet the small of the back. The chair should be of rigid construction in order to give support and steadiness. Adjustable chairs may at times be necessary for special work, but they are not otherwise advisable, for they are harmful when incorrectly adjusted and are often unsteady. The seat of the chair should be solid. Cane bottoms are particularly undesirable, for they

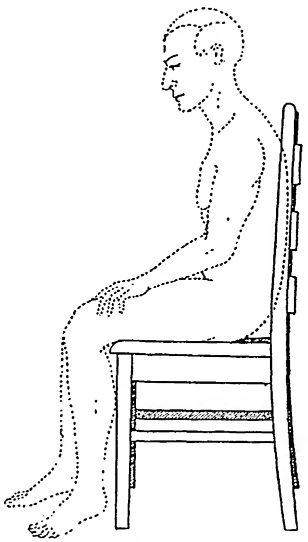


Figure 60A. BAD SITTING POSTURE.
The chair does not give support to the lower part of the back.

weaken rapidly and the worker is soon sitting on a wooden bar which crosses under the middle of the thighs. The seat should furnish support directly under the body.

The worker in an improperly designed seat tends to sit forward on the front part of the chair and use the back of the chair only during intervals of rest from the fatigue produced by sitting with no support to the back.

In occupations of a nature which make back support impossible, it is at times advantageous to tilt the seat of the stool or bench so that the front is slightly higher than the rear. This

has a tendency to throw the shoulders back and to counteract the bowing of the back.

The height of the chair should be such as to allow the worker's feet to rest firmly upon the ground, neither raised at the heel nor thrown sideways or in front to meet the floor. Each length of leg requires its own height of chair. By arranging the work on the table or bench so that a minimum of motion is required, efficiency as well as relief from strain and fatigue is achieved. The arrangement of material and of machinery is particularly

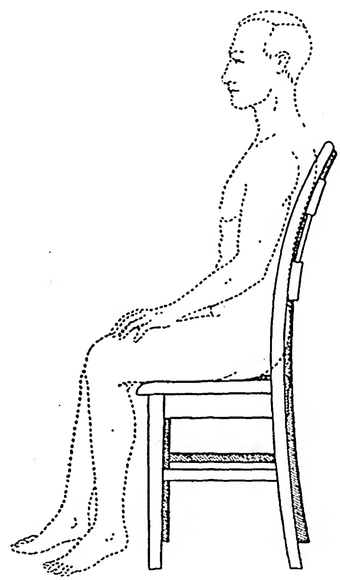


Figure 60B. Good Sitting Posture.
Chair with shallow seat and support for lower part of back.

important for avoidance of cramped or strained positions. A worker at a sewing machine who keeps scissors or other implements in her lap by supporting one leg on the machine is in a cramped and strained position which leads to fatigue and to pains in muscles and ligaments. Likewise an operator who is forced to watch his work with the head thrown to one side, as in avoiding glare from improper lighting or because of obstructed vision due to poor arrangement of the machinery, is contributing greatly to his fatigue, and also to the far-reaching effects of poor body mechanics.

Mechanism of Human Locomotion.

In walking, the body is leaned forward until a line perpendicular to the earth and passing through the center of gravity is brought in front of the base formed by the feet. Equilibrium is thus disturbed and if unchecked the body would fall. The equilibrium is restored by swinging forward one leg and supplying a base of support with the foot of that leg. During the instant that equilibrium is restored the body is supported on both feet; during the remainder of the pace it is supported on only one foot. To effect the next pace the foot in the rear is "unrolled" on the ground from heel to toe, rises on its toe, and with a thrust shoves the body forward to bring the center of gravity in front of the foot resting upon the ground. The foot which has furnished the propulsion then swings to the front to restore equilibrium. The regular repetition of this sequence constitutes the act of walking.

The movements of walking are complicated by oscillatory movements of parts of the body other than the legs. The feet exert a lateral pressure as well as a vertical pressure, and the body is thrown from side to side with each pace and at the same time partially rotated at the hips. The oscillation of the trunk is compensated by a swinging motion of the arms; as the right leg advances, the left arm swings forward, and as the left leg advances, the right arm is swung.

The swinging of the leg forward to restore the equilibrium of the body in walking is not accomplished alone by the pendulum-like action of the free limb. The period of the leg as a pendulum is too slow to swing forward under its weight alone; instead its forward movement is accelerated by the pull of muscles. Unlike most other animals—the horse, for example—the human leg has a mass of muscle, the calf, relatively near to its extremity. This mass adds inertia to the movements of the legs—that is, increases its radius of gyration.

The act of running is essentially of the same character as walking, with the difference that the period of double support with both feet on the ground simultaneously is missing. The legs alternate in single support of the body, but between the instants of support there is a time in each step when the body is completely off the ground.

CHAPTER XIX

MUSCULAR ACTIVITY AND FATIGUE

THERE are in the body three types of muscular tissue: the so-called involuntary or smooth muscle of the visceral organs such as the intestines and bladder; the heart muscle; and the striated or skeletal muscle through which voluntary movements are performed. The fundamental character of muscular action is the same for all three types. They resemble one another in general appearance, but they are distinguished by microscopic differences in structure and by the character of their contraction. Smooth or involuntary muscle contracts slowly, and its contraction may be maintained for a long time without fatigue. Voluntary muscle contracts rapidly, but it also becomes fatigued rapidly. Heart muscle is intermediate in character between the other two types, but it has in addition the property of developing its own stimulus for rhythmic contraction. The discussion below applies particularly to voluntary muscle.

Structure of a Muscle.

A muscle, the biceps for example, is composed of many thousands of muscle fibers placed parallel and bound together by connective tissue; the whole bundle is surrounded by a sheath of connective tissue. The muscle fiber is the unit of muscle structure, and is in fact a replica of the entire muscle. A muscle fiber is a cylindrical thread with a diameter varying between 0.1 and 0.01 millimeters and with a length not exceeding 36 millimeters (1.44 inches). It consists of an elongated spindle of semigelatinous muscular tissue. This muscular tissue has a fine structure showing both longitudinal and cross striations, which are marked out by alternate areas more or less dense in the viscous tissue. Each muscle fiber is surrounded by a sheath of connective tissue. This sheath extends beyond the muscular tissue to form a minute cord for each fiber. The muscle is formed by rows of these minute muscle fibers with their terminal exten-

sions of connective tissue joined together. The extensions of these combined cords of connective tissue at each end of the muscle form the tendons of the muscle. The tendons are attached to the bones upon which the muscle exerts its traction.

Arrangement of Antagonistic Muscles.

A nerve fiber runs to each of the muscle fibers. When impulses pass down these nerve fibers the muscle contracts as a whole; when the impulses cease the muscle relaxes. A muscle

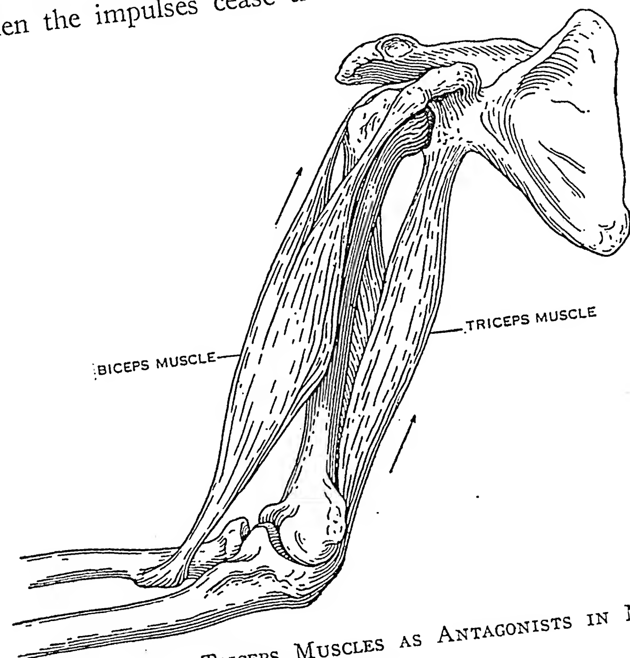


Figure 61. Biceps and Triceps Muscles as Antagonists in Moving the Forearm.

performs its work only in the direction in which it contracts; the relaxation is entirely passive. Before further work can be performed the muscle must be elongated. This elongation is accomplished through the arrangement of antagonistic muscles. Thus the biceps muscle on the front of the upper arm by contracting pulls up or flexes the forearm; the triceps muscle on the back of the arm acts to extend the forearm to its original position, thus enabling the biceps to contract once more. This arrangement of muscles in antagonistic pairs also allows the various parts of the body to be held rigid. When the biceps and

triceps are contracted simultaneously the forearm is held rigid. A similar action in the muscles on both sides of the spine maintains the body in the erect position.

Mechanics of Muscular Contraction.

When a muscle is stimulated by a nervous impulse it undergoes a change of state resulting in contraction. The muscle passes temporarily into a new elastic condition and develops new potential energy, so that it exerts a pull upon the structures to which it is attached. If the pull of the muscle is sufficient to overcome the resistance, it shortens, its potential energy is converted into kinetic energy, and mechanical work is done. In contracting, the muscle does not change its volume; it merely changes its shape, becoming shorter and thicker. To effect the contraction the muscle fibers do not pull upon the connective tissue sheaths which surround them; instead, the viscous muscular tissue which fills the sheaths tends to become more spherical in shape. In doing so it exerts a lateral force. This lateral force tends to widen the sheaths and to shorten them. The resultant of all these forces is a pull exerted through the sheaths and transmitted to the tendons at the ends of the muscle.

The lateral forces of the muscular tissue have their greatest longitudinal resultant when the muscle fibers are stretched out to their full length. Correspondingly, as the fibers become more spherical the longitudinal resultant of the forces diminishes; if the fibers were to become completely spherical, the forces would be exerted equally in all directions and no pull would result. As the action of the muscle is the sum of the actions of all of its fibers, the muscle also has its greatest pulling force when it is stretched out to the greatest extent; as the muscle shortens this pulling force is diminished.

The pulling force of a muscle, when measured as external work, is modified by the mechanical advantage of the lever system through which it is transmitted, a fact that may be illustrated by the action of the biceps muscle. This muscle is attached by one end to the shoulder, and by the other end to the bones of the forearm a short distance below the elbow. When the muscle contracts it flexes the forearm. When the forearm is fully ex-

tended the biceps pulls at a great mechanical disadvantage, for only a small fraction of its force is used in flexing the forearm, and a much larger component is uselessly expended owing to the direction at which the bones are placed. As the arm rises the biceps pulls to better mechanical advantage, and a greater proportion of its force is in the direction of flexing the forearm. When the arm is fully extended the biceps is stretched to its greatest length and has its maximum pulling force; as the arm rises the biceps shortens and its pulling force is diminished. The diminished pull of the biceps is compensated by the rising mechanical advantage of the lever system to which it is applied. As a result the lifting power at the hand is nearly the same from full extension of the forearm to half flexion. Beyond the point of half flexion, both the pull of the biceps and the mechanical advantage of the lever system diminish, so that the lifting power falls off rapidly.

Chemical Changes in a Muscle During Contraction and Relaxation.

The muscles store up carbohydrate in the form of glycogen; their action in this respect is similar to that of the liver although less noticeable. The glycogen is formed in the muscles from the sugar in the circulating blood; it affords the main fuel for the action of muscles. During contraction the glycogen is broken down into lactic acid. In some way, not fully understood at present, the inorganic phosphates in the muscle play a part in this reaction, possibly by combining with carbohydrate as an intermediary step in its conversion to lactic acid. The breaking down of glycogen to lactic acid does not require oxygen, and so the muscle does not consume oxygen during its contraction. Some heat is liberated from the conversion of glycogen to lactic acid, but a much greater amount of heat is liberated during the period of recovery which follows the contraction. If the contraction is maintained the destruction of glycogen continues and lactic acid accumulates; as a result the muscle becomes fatigued.

Oxygen is consumed by the muscle during the reparative period following contraction; if oxygen is not supplied, the muscle fails to recover and becomes incapable of further action.

During the reparative process about one-fifth of the lactic acid formed during the contraction is burned, oxygen is used and carbon dioxide is produced. By means of the energy thus supplied the remaining four-fifths of the lactic acid are converted back into glycogen. The small deficit of glycogen is made up from the sugar in the blood, and the muscle is thus restored to its previous state of readiness for response.

A supply of blood is necessary for the recovery process in the muscle; the blood furnishes oxygen for the oxidation of part of the lactic acid in liberating the energy for the conversion of the rest back to glycogen; the blood removes the carbon dioxide produced and distributes the heat which arises in the muscle during the formation of lactic acid and its reconversion; it also replenishes the supply of glycogen necessary for continuation of the muscular activity.

Static Effort.

When a muscle is stimulated for a certain period, but is not allowed to contract, the conversion of glycogen takes place throughout the period. There is a continual dissipation of energy. In this respect a muscle is analogous to an electromagnet which can be made to hold up an object only by passing a current continuously through its coil. The passage of current involves a liberation of energy as heat. A muscle while making a static effort dissipates energy. The accumulation of lactic acid under this particular condition induces fatigue in the muscle. The destruction of lactic acid and reformation of glycogen cannot occur until the muscle is allowed to relax. Static effort thus leads to fatigue more rapidly than does a muscular activity doing external work and involving both contraction and relaxation.

Optimum Speed and Internal Work.

Muscular tissue is a viscous material; it offers resistance to change of shape during contraction, and energy is expended in overcoming this internal resistance. If the muscle contracts slowly the energy thus expended is slight, but the internal resistance increases with the speed of contraction and at a more than proportional rate. At the maximum speed at which the

muscle can be made to contract, all of its available energy is used in overcoming the internal resistance and none is left to perform work. When the muscle does external work, as in lifting an object, the speed of contraction is retarded by the load. For each amount of load upon the muscle there is a speed at which the work can be performed most efficiently. High speed is wasteful, for if the speed is forced beyond the optimum for the load,

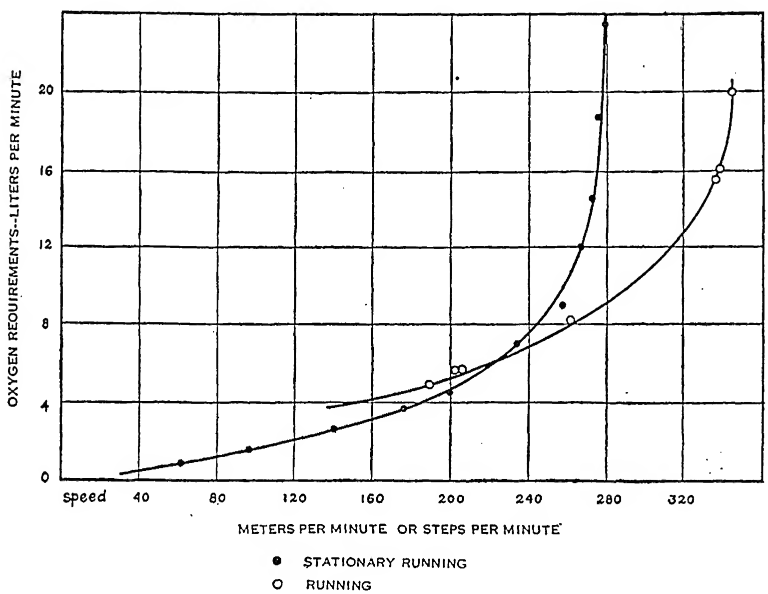


Figure 62. Oxygen Requirement in Relation to Speed of Performance. The oxygen requirement (oxygen consumption plus oxygen debt) is shown for various rates of activity. As the speed of performance increases the oxygen requirement also increases but at a more than proportionate rate. (After A. V. Hill.)

the increasing internal resistance consumes energy and fatigue develops rapidly. Sustained activity can be performed only at or below the optimum speed. Figure 62 shows the amount of oxygen required in relation to the speed of performance during stationary walking and running. The oxygen requirement expresses the energy expended by the muscles in performing the exercise; but it does not exactly correspond to the oxygen consumed during the time of the work, for, as will be seen later, the body may develop a deficit of oxygen which is made up after the

work is completed. At sixty steps a minute the oxygen requirement was 0.5 liter a minute. On doubling the rate, 120 steps a minute, the oxygen requirement was also doubled; the speed had not yet become sufficient to require a large proportion of the energy in overcoming the resistance of the viscous muscular tissue. When the speed was increased to 180 steps a minute the oxygen

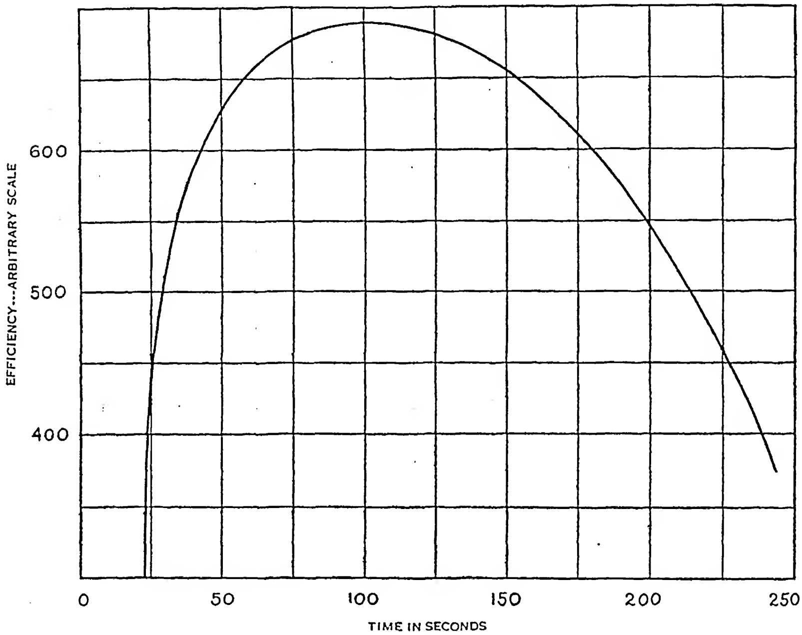


Figure 63. Muscular Efficiency and Its Optimum as Illustrated in Climbing Stairs at Different Speeds.

The efficiency recorded is the inverse of the oxygen requirement for the effort. The efficiency is diminished by both fast and slow rates of climbing, thus indicating that there is an optimum rate for the effort. (After A. V. Hill.)

requirement rose to 4 liters, or eight times that of the initial speed. An increase to 240 steps a minute brought the oxygen requirement to 8 liters, while at a rate of 280 steps a minute the oxygen requirement rose to 24 liters, an exertion that could be maintained for less than a minute.

Other Factors Determining Speed.

The resistance of the viscous muscular tissue is one of the main factors in determining the efficient rate for work, but other

factors also play a part. One of these factors is the mechanics of the part of the body used. The natural period, or rate of swing, of the arm or leg as a pendulum plays a part in establishing the optimum speed of operation. In some cases, such as in pounding with a sledge hammer or in rowing, the rate of work is influenced by the rate of breathing; a racing crew pulls raggedly when the rate of stroke is too slow to permit sufficiently rapid breathing, while a high rate, forty-five or more strokes a minute, cannot be maintained for long because breathing becomes too shallow to be effective.

A part of the strain of work is mental; some of this mental factor is removed in acts which are rhythmically repeated, for after practice the act becomes a timed reflex. The timing of the act by some outside influence, such as the music in dancing, the pace-maker in running, or the coxswain of a crew, further removes the necessity for mental strain, for the outside factor then supplies the stimulus at the proper time, and the act follows almost unconsciously. The establishment of rate by sensory impressions from some rhythmic source outside of the body is seen particularly in men marching to the music of drums. If the work performed is not rhythmic in character the outside influence then becomes a disturbing factor; music hinders rather than helps a worker using a typewriter or telegrapher sending messages.

Influence of Muscular Activity upon Other Bodily Functions.

Muscular activity influences the function of all parts of the body. The consumption of oxygen by the body varies in proportion to the rate of muscular activity, and the amount of air breathed varies in a corresponding degree. The response made by breathing to an increased rate of muscular activity is not instantaneous; from one to two minutes is required for the establishment of the new volume of breathing. Likewise when the exertion is stopped, breathing does not fall immediately to the resting level, but returns only gradually. The circulation is altered by exertion; the arteries supplying the muscles dilate, thus allowing a greater flow of blood to them. This dilation is in part compensated by the constriction of arteries in other parts of the body, particularly in the abdominal organs, and by an increased

pumping action of the heart (see Chapter VI), as is evident in the increased pulse for a time after the exertion. The heat produced in the exercising muscles raises their temperature slightly; if the exertion is vigorous the temperature of the whole body rises. Dissipation of the increased amount of heat involves a dilation of the blood vessels in the skin, and a greater activity of the sweat glands. During muscular exertion the glycogen in the liver is mobilized in order that the greater utilization of sugar by the muscles may be compensated. After exertion the metabolism of the body is elevated, and even in the resting state remains above the basal rate for many hours.

Influence of Bodily Condition upon Muscular Activity.

All the functions of the body are influenced by muscular activity and participate in the activity. The coöperation of these functions is essential for the performance of the activity. When any one function is limited, muscular activity is correspondingly limited. The heart is the main organ determining the extent to which muscular activity can be sustained. The effects of athletic training, aside from the development of skill, are largely concerned with the development of the heart. The two factors concerned in this development are the increase in size of the heart so that it can pump a greater volume of blood at each stroke, and the control of its rate, so that it will not become excessively fast and thus cut down the flow of blood by incompletely filling between beats. The rate of the heart is controlled by the nervous system; the less irritable the nervous system, the slower will be the rate of the heart in exercise. A well-trained athlete performing work which does not carry him to exhaustion has a pulse rate running up to but rarely exceeding 140 to 170 beats a minute. Under the same exertion a man in poor physical condition has a pulse of 190 or even higher, but the volume of blood which his heart pumps is less than that of the trained man, even though their hearts may be of the same size. Tobacco and coffee, if used in excess, increase the rate at which the heart beats; thus these substances diminish a man's "wind"—that is, make him short of breath on exertion. Shortness of breath is due to a failure of the circulation of blood to keep pace with the

exertion, and is not due to any inability of the lungs or muscles involved in breathing. A man with valvular disease of the heart becomes short of breath on slight exertion, or even while at rest, not because his muscles or his lungs are deficient, but because his heart does not pump the normal amount of blood; consequently the amount of oxygen reaching his tissues is less than normal.

Lack of cooling power in the air, as determined by its temperature, its movement, and its humidity, diminishes or limits muscular exertion and also the incentive to exertion. This topic will be discussed at length in Chapters XX and XXI. A similar limitation may result from the inhalation of carbon monoxide from the exhaust gas of internal-combustion engines or from other sources. The influence of organs, even those as remotely connected with muscular exertion as the pancreas and thyroid gland, nevertheless profoundly influence physical vigor. A man with myxedema lacks inclination for muscular exertion; a man with exophthalmic goiter has the incentive in high degree, but is too easily fatigued to do work; the man with serious diabetes is too weak.

As the nervous system controls the muscles and all the correlated functions of the body, its condition influences muscular exertion. This influence may be shown in variations in the action exercised by the cerebrum upon the reflexes. During excitement or other strong emotions, exceptional muscular exertions may be performed; the maniac with sustained excitement illustrates this influence in exaggerated degree. Depressing emotional influences have the reverse effect and make muscular exertion difficult and wearisome; again the maniac in his depressed state furnishes an illustration. In a less degree muscular activity is influenced by the enthusiasms and despondencies of everyday life.

The nervous influence upon muscular exertion is not limited to the emotional states, but is varied by any factor which disturbs the normal balance of the nervous system. Absorption of the products of infection, disturbance of the glands of internal secretion, and poisons such as carbon monoxide, or alcohol and other hydro-carbons, all influence the nervous system. Even

slight infections diminish muscular activity and predispose to fatigue.

Maximum of Human Power.

The maximum power that can be developed during an exertion involving the use of a large number of muscles, varies with the length of time over which the task is extended. A healthy man with well-developed muscles, working very hard, can for eight or ten hours sustain an average production of 0.1 horse power. It has been found by dietary studies on men doing heavy work, such as that of lumbermen, that the total daily expenditures may reach a value as high as 6,000 kilocalories. Of this total at least 4,000 are expended during a ten-hour working-day. Of these 4,000 kilocalories not more than 800 are expended as work, the remainder being dissipated as heat. Eight hundred kilocalories in ten hours is equivalent to work at the rate of 0.1 horse power. The same man attempting to do work at the rate of 0.2 horse power could not sustain it for more than two or three hours without becoming exhausted. In rowing in racing shells trained athletes do work up to 0.5 or 0.6 of a horse power during a race of twenty minutes. A man can, for ten or fifteen seconds, develop as much as 3 to 3.5 horse power, as in a hundred-yard dash.

The limiting factor in maintaining vigorous exertion is the rate at which oxygen can be supplied to the tissues, and this depends upon the capability of the heart. The muscles by forming lactic acid can perform vigorous work for a short time without oxygen; a large amount of oxidation may thus be put off to a time after the exertion is ended. This delayed oxidation occurs during the recovery process; the heavy breathing after the exertion and the slow return of the heart to the normal rate are indications of this process. During exertion the tissues run into debt for oxygen, but the extent to which they can do so is limited. Even in the most favorable cases the body becomes incapable of further exertion and is completely fatigued when an oxygen debt of about fifteen liters has been incurred. The maximum rate at which oxygen can be supplied to the body by the circulation depends upon the development and physical state of

the individual, but the maximum for the best-developed men in the prime of condition is probably not much more than four liters a minute; it is much less for most men. If the exertion is at a sufficiently moderate rate to require less than the maximum of oxygen which can be supplied by the blood, the exertion can be maintained for a comparatively long time before the muscles become fatigued. If the exertion requires more oxygen than can be supplied to them, the exertion is limited by the increasing oxygen debt; when the full debt is incurred, the exertion ceases. The fact that an oxygen debt can be incurred makes it possible for the body to perform extremely violent muscular exertions for a short time.

Fatigue from Accumulation of End Products.

When a muscle is made to contract for a time without being allowed to relax, it gradually loses its force and finally relaxes involuntarily. The muscle is then said to be fatigued. This form of fatigue develops as a result of the accumulation of lactic acid, and perhaps other substances, produced during the contraction. If a muscle alternately contracts and relaxes, the time within which fatigue develops depends upon the work done by the muscle at each contraction, upon the frequency of the contractions, and the duration of the relaxation periods. The classical picture of the fatiguing muscle is afforded by a finger ergometer. In using this apparatus the hand rests on its back on a table; a cord extending over a pulley and bearing at its end a weight is attached to the index finger. Each time the finger is bent it lifts the weight. The contractions are recorded by a pointer attached to the weight and writing on the surface of a strip of smoked paper on a rotating drum. The type of record thus obtained is shown in Figure 65—1. The contractions of the muscle are indicated as vertical lines, and in this record occur at intervals of 1 a second. The first few contractions increase progressively in height. This indicates an increase in the force and extent of the contraction of the muscle, and is due to the muscle "warming up." Following this ascending portion, the contractions are for a time approximately of uniform height. A gradual decline in height then follows; this decline indicates the development of

fatigue. The muscle is then allowed to rest for a short time, and the action then resumed; the contractions, Figure 65—2 now are equal in height to those in the middle of the previous record. That the rest has not been of sufficient duration to allow complete recovery is indicated by the fact that in the second series of contractions fatigue develops more rapidly than in the first. Figure 65—3 represents a record in which the finger contracted at twice

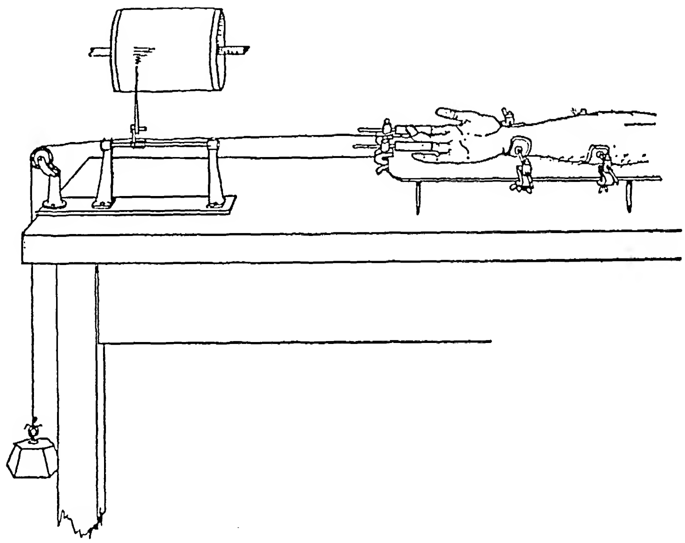


Figure 64. FINGER ERGOGRAPH.

Apparatus for recording the work done by the finger in repeatedly lifting a weight. The stylus attached to the cord carrying the weight writes upon the paper covering the revolving drum. Typical records are shown in Figure 56.

the rate used in making the previous records. In this case fatigue develops in much less than half the time of the first record.

In the case of the finger ergometer used for short periods of work as shown here, fatigue develops largely from the accumulation of unoxidized end products. Fatigue from this cause is not, however, the common cause of fatigue in industrial procedure. Fatigue from the accumulation of end products in the muscle develops only as a result of comparatively severe or sustained exertion of the muscle. The rate of contraction of the finger working the ergometer could have been made with a sufficient

period between each contraction to allow restoration of the muscle, and yet fatigue would eventually have developed.

Fatigue from Sugar Depletion.

Fatigue may occur from sugar depletion resulting from long-sustained vigorous exertion, such as that of the Marathon runner; he collapses when he has utilized all of the available store of

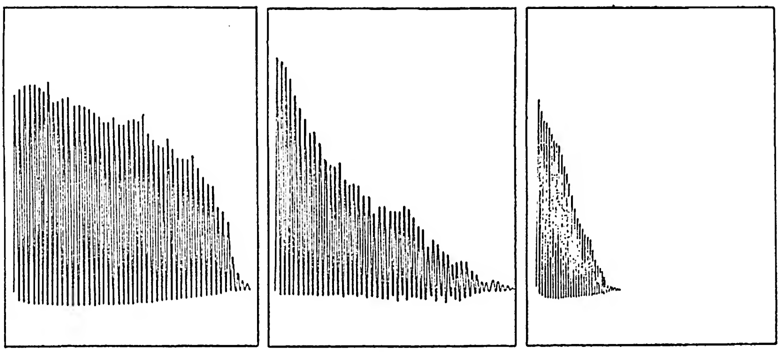


Figure 65. Tracings from Ergograph.

(1) Finger lifting weight at the rate of 60 times a minute: The diminishing amplitude of the movement shows the development of fatigue.

(2) Continuation of tracing (1) made after a short rest, showing only partial recovery from the fatigue of the previous work.

(3) Finger lifting the weight at the rate of 120 times a minute, showing the rapid development of fatigue at the increased rate of movement.

carbohydrate in his body, but he may resume running after he has been fed sugar. Sugar depletion rarely develops to its full extent in ordinary occupations, and yet in a lesser degree it plays a part in industrial fatigue. The immediate fuel for muscular activity is carbohydrates; on a diet of fat the muscles act less efficiently and more heat results from the same amount of external work. After meals containing carbohydrate a greater proportion of this material is burned in the muscle and less conversion from fat is required, so that work is performed with less fatigue. Some hours after the meal the supply of carbohydrate stored in the body is diminished and more fat is utilized. The efficiency of the work diminishes and fatigue develops more rapidly. At this time the taking of readily assimilated carbohydrate in the form of sugar as candy or in tea is stimulating and

helps to relieve the fatigue. The extent to which carbohydrate is being utilized is indicated by the respiratory quotient (see Chapter IV). In most persons a fall in the quotient occurs late in the morning and again late in the afternoon. It indicates the proper period between meals.

Fatigue as a Nervous Phenomenon.

The ordinary type of fatigue encountered in the day's work in industry is largely a phenomenon of the nervous system. In prolonged work of moderate intensity the nervous system tires before the muscles do. Under comparable conditions of work, the length of time required for this type of fatigue to develop depends upon the general health and vigor of the individual. It is strongly influenced by the activity of the higher cerebral centers; worry, discouragement, or any depressive emotion hastens its development. In the opposite direction, fatigue of the nervous system resulting from work exerts an influence upon the cerebral centers and causes emotional depression. The cerebral depression developed from the fatigue of a small group of muscles may influence the whole of the nervous system, radiating its effects into every part of the body, so that the legs may feel tired as a result of using the hands. Fatigue of the eyes exemplifies this.

The extent of the expenditure of energy by the body as a whole plays little part in this type of fatigue. Comparatively hard work involving the activity of many muscles, but none used to an extreme degree, may result in less general fatigue than a light task involving the intensive activity of a small group of muscle. Standing rigidly at attention, an act accomplished through a group of muscles working at extreme mechanical disadvantage, leads to fatigue more rapidly than does walking, although the energy expenditure of walking is much the greater.

CHAPTER XX

TEMPERATURE OF THE BODY AND ITS REGULATION

Advantages of a Constant Temperature.

The foodstuffs, after being stored or built up into the tissues of the body, are burned, and the energy is liberated as work and heat. This combustion, which is the very essence of life, is a chemical reaction. The rate at which chemical reactions occur, their velocity, is influenced by the temperature; at low temperatures they proceed slowly, at high more intensely. The reactions in the body also obey this rule. If the temperature of the body is lowered all of its functions are depressed; the rate at which impulses are transmitted in nerves decreases, the heart beats more slowly, and the mental activity diminishes.

The so-called "cold-blooded" animals do not regulate the temperature of their bodies and are subject to the temperature of their surroundings. The frog is motionless on cold days and is active only on warm days. During the winter months this animal goes down into the mud a little below the frost line; its vital combustion is depressed by the temperature to such a degree that it is able to live through the winter on the small store of food in its tissues.

Animals which maintain the temperature of their bodies constant can carry on a high degree of activity independently of their surrounding temperature. The so-called "warm-blooded animals" are birds, and most mammals, including man. A few mammals, such as bears and other hibernating animals, are warm-blooded for part of the year; but during the time of their winter sleep their body temperature falls and with it the energy expenditure and the need for food.

Temperature of the Body.

The temperature of all warm-blooded animals is nearly constant in each, but in different species ranges from 37° to 43° C.

(98.5° to 110° F.) with the temperature of man near the lesser figure and that of birds at the greater. The temperature recorded varies to some extent with the part of the body from which it is taken. With the thermometer placed in the rectum or in the stream of urine, the temperature is approximately 1° F. higher than the temperature of the mouth. The higher values represent more nearly the real temperature of the internal structures of the body than does the temperature of the mouth. The temperature of the skin varies greatly, for it is through the skin that the heat dissipation is regulated.

There is a slight individual variation in the temperature of normal men; furthermore, the temperature of each individual varies daily through a range of 1° to 3° F. This diurnal variation runs a regular course; body temperature is at its minimum between three and five o'clock in the morning, and at its maximum between three and five o'clock in the afternoon. In those who work at night and sleep during the day, the diurnal variation is somewhat diminished; only in rare cases is it reversed.

Source and Distribution of Heat.

The heat which maintains the body at its normal temperature is derived largely from the contraction of muscles, and to a less extent from the metabolic activities of the liver and other glands. The heart and those muscles which carry out the movements of respiration are active even when the other muscles are relaxed. But even the resting muscles produce some heat, for the relaxation is never complete. The slight pull, or tonus, which distinguishes the living muscle from the dead, involves a continual slight oxidation and a corresponding production of heat. The basal metabolism, as discussed in Chapter IV, represents this minimum production of heat, which for all normal persons is about 39 kilocalories (160 B.T.U.) per hour for each square meter of body surface. From this level the heat production may rise ten-, or even fifteen-fold in vigorous muscular exertion.

The circulating blood serves to distribute the heat throughout the body, and tends to keep the temperature of all parts nearly uniform. The temperature of an exercising muscle rises above

the temperature of the rest of the body; but the rise is slight, for the blood flowing through the muscle is heated to the same temperature, and on flowing to other parts of the body distributes the heat to areas which are less warm. Blood after passing through the skin returns to the heart at a lower temperature.

Regulation of Body Temperature.

Warm-blooded animals should properly be called animals of uniform temperature, for they maintain their temperature uniform within narrow limits. They do so by means of two forms of regulation—physical regulation and chemical regulation. Physical regulation is the control of the heat loss from the surface of the body. It is effected by the adjustment of the flow of blood through the skin and by the evaporation of sweat from the surface. When the flow of blood through the skin and the secretion of sweat are reduced to their lowest possible amounts, the heat loss through the skin is at its minimum. If the surrounding temperature is so low that the resting heat production of the body is insufficient to maintain the normal temperature, chemical regulation is called into play. It acts as a form of enforced exercise. The metabolism is increased by voluntary contractions of the muscles in stretching the arms, yawning, and stamping, and finally by shivering. Chemical regulation can be aided by the increase in metabolism which results from taking food, particularly protein; but ordinarily chemical regulation is the less frequently employed of the two modes of controlling the temperature of the body, for we limit the loss of heat from the skin by means of clothing and by heating the air artificially.

Physical Regulation of Temperature.

Eighty per cent or more of the elimination of heat from the body occurs from the skin. The loss of heat from this surface is not due to direct conduction of heat from the underlying tissues and organs of the body. Beneath the skin is a layer of fat which insulates the body and diminishes the conduction of heat from the tissues to the overlying skin. The skin may attain a low temperature, while the tissues a half inch beneath it

are at the normal body temperature. The greater part of the heat eliminated from the skin is brought to it by the circulating blood; the amount is largely dependent upon the volume of blood flowing through the skin. Elimination of heat is assisted by the latent heat of evaporation of sweat; the secretion of sweat is varied as needed under nervous control.

The various arrangements and processes concerned in regulating the loss of heat from the body can be illustrated by comparison with the hot-water heating system of a building. The heater in the building consists of a fire box surrounded by an annular water space. The combustion in the fire box is analogous to that in the active muscles, and the water surrounding it to the blood flowing through the vessels of the body. The water heater is covered by insulating material such as asbestos; in the body the corresponding layer is fat. From the top of the water space in the heater, a pipe extends to a radiator through which the water circulates and returns to the heater through a second pipe. The flow of water to the radiator is controlled by a valve. The radiator represents the skin of the body, and the pipes correspond to the blood vessels carrying the blood to and from the vessels in the skin. The action of the valve has its analogy in the constriction and dilatation of the vessels under the influence of the nerves. The loss of heat through evaporation, although not represented, would be analogous to wet cloths placed over the radiator or to a stream of water in varying amounts trickling over its surface.

In certain respects the heat-regulating system of the body and the hot-water heating arrangement here described are employed in diametrically opposite ways. In the hot-water system the attempt is made to maintain a uniform temperature in the room in which the radiator is placed; in the body, on the contrary, a uniform temperature is maintained in the circulating fluid, the blood, by regulating the amount of heat eliminated in proportion to the intensity of the fire. In general, the means through which heat is produced and lost in the water-heating system and in the body are closely analogous. Thus in the two systems the means by which heat is lost are:

In the hot-water heater	*In the body*
(1) By putting in fuel or water at a temperature lower than that of the heater.	(1) By the ingestion of food and drink at a temperature lower than that of the body.
(2) By air passing out of the flue at a temperature above that of the heater.	(2) By the warmth of expired air above that inspired and the heat used in volatilizing water to moisten the air breathed.
(3) By conduction through the walls of the boiler.	(3) By conduction from the deep tissues through the layer of fat.
(4) By conduction from the radiator heated by the stream of water.	(4) By conduction from the skin, heated by the flow of blood.
(5) By placing wet cloths on the radiator.	(5) By evaporation of sweat.

The following table presents a typical example showing the relative amounts of heat lost from the body in the various ways. The man from whom the data were obtained remained for twenty-four hours in a comfortably heated room. His energy expenditure was low. The percentages of loss were:

(1) By food and water..........	1.8% or	48 Cal. or	202 B. T. U.
(2) By expired air..............	10.7% or	182 " "	1,064 B. T. U.
(3) By evaporation from skin....	14.5% or	364 " "	1,456 B. T. U.
(4) By radiation and conduction from the skin.............	73.0% or	1,792 " "	7,168 B. T. U.
	100.0% or	2,386 Cal. or	9,890 B. T. U.

Automatic Operation of the Physical Regulation.

The physical process regulating body temperature consists in adjustment of the flow of blood to the skin and in varying the rate at which perspiration is secreted upon the surface. As the skin is heated by the blood flowing through it, the rate of heat loss by conduction and radiation to the air is determined by the difference between the temperature which is thus produced in the skin and that of the surrounding air. The amount of heat lost through the evaporation of sweat is determined by the rate of secretion of this fluid and by the capacity of the air to take

up moisture as vapor. Sweat wiped off in liquid form does not assist in cooling the body.

The size of the blood vessels in the skin and the activity of the sweat glands are regulated by impulses reaching them through nerves. These nerves are influenced by two controlling factors: (1) a center of control in the medulla oblongata at the base of the brain; and (2) a stabilizing reflex influenced by conditions in the skin itself. The center in the brain controls heat elimination so as to compensate for the variations in heat production within the body, and the cutaneous factor adjusts the skin to changes in the atmospheric conditions which affect the rate of cooling from the skin. The blood vessels and sweat glands of the skin are acted upon directly by conditions in the skin. But the activity of this reflex is in turn influenced by the center in the brain.

The controlling center in the brain acts like a thermostat. It responds to changes in the temperature of the blood flowing through it. A rise in the temperature of the blood causes the center to decrease the strength of the impulses which normally act upon the vessels in the skin, thus allowing them to dilate so as to afford a larger blood flow and greater heat loss. A fall in the temperature of the blood results in a constriction of the vessels so that the loss of heat is lessened.

The stabilizing reflex influenced by conditions in the skin is not adjusted to regulate the skin to any fixed temperature. The center in the brain influences this reflex, so that instead of a fixed skin temperature it maintains a certain rate of loss of heat. It does this by altering the size of the vessels and the secretion of sweat in accord with variations in the cooling power of the air acting upon the skin.

An example may illustrate the working of the two controls. As a result of physical exertion the temperature of the body is slightly raised. The blood at the slightly elevated temperature stimulates the center of heat control in the brain. This center then influences the vessels in the skin to dilate and the sweat glands to increase their activity so as to effect a greater elimination of heat. If the surroundings are cool, the redness of the skin and the secretion of sweat are less evident than if the sur-

roundings are warm, for the skin does not, under the cool surroundings, need to make the same effort in order to produce the necessary dissipation of heat. The local reaction is seen when the skin becomes red and also perspires only on a limited area as a result of warming, such as placing only the hands in hot water. In this condition the changes are brought about with little coöperation from the center in the brain. Body temperature does not rise unless the heat is extreme or the air is both warm and very moist and still. The reflex in the skin excited by the heat of the surrounding air makes the necessary adjustments.

Chemical Regulation of Body Temperature.

Both the center in the brain and the reflex control from the skin can excite the chemical control of temperature. This control is called into play by the center when the temperature of the body falls below normal, and by the sensory impressions from the skin when the rate of cooling from the surface becomes excessive. The action of the thermostatic center in the brain stimulates the muscles to a greater tonicity and finally to shivering as a means of increasing the temperature of the body. Similarly, the reflex from the skin stimulates the muscles in order to prevent too great cooling of the skin, even though the body temperature is not depressed. The close correlation between the temperature of the skin and the state of tone of the muscles and hence the incentive to muscular activity, is an important aspect of the influence of climate.

Sensations of Warmth and Coldness.

Sensations of warmth and coldness are not reliable indications of the temperature of the body; they are indications only of the temperature of the skin, as is illustrated in the sensations of chilliness at the commencement of fever. Contrariwise, when alcohol is taken the vessels of the skin dilate and a sensation of warmth is experienced, although in fact the temperature of the body falls. These sensations are indicators merely of the activity of the control located in the skin; they are influenced both by atmospheric conditions and by the production of heat within the body. The

temperature of the skin at which a sensation of cold occurs is altered by long exposure to cold surroundings, so that certain areas of the skin, such as the hands and face, become relatively hardened. (The sensations of temperature arising from the skin are discussed more at length in Chapter XV.)

Cooling by Evaporation.

The evaporation of water from the skin is a most effective means of cooling. Each gram of water requires 0.54 kilocalories (64 B.T.U. per ounce) to convert it into vapor. During a day of strenuous exertion under hot surroundings as much as ten pounds of water may be lost through the skin, although much of it may not be evaporated. Man and the horse are among the few animals which have general sweating. Other animals, notably the dog, lose heat through the evaporation of water from the mouth by the rapid movement of air over the tongue in panting.

Perspiration is continually secreted upon the skin. But when the body is cool and heat dissipation is largely effected by conduction and radiation the small amount secreted evaporates rapidly and is not observed. Such perspiration is known as insensible perspiration. It becomes apparent if an area of the skin, such as an arm is inclosed in a glass jar, for the air in the jar becomes saturated with moisture, and dew is deposited upon the sides of the vessel.

As the temperature of the skin rises, either as a result of external heat or of exertion, the secretion of perspiration is increased. When the rate of evaporation is not sufficient to remove the water as rapidly as it is secreted, the perspiration becomes apparent as beads of moisture or as a film over the surface. Sweat which does not evaporate does not assist in cooling the body; it is a waste of fluid and sometimes involves also a considerable loss of sodium chloride.

When the skin has become bathed with sweat as a result of exertion or warm surroundings, time is required for the moisture to evaporate even after the exertion has been stopped or the surroundings have become cool. The skin is cooled with excessive rapidity by this delayed evaporation. As a result, the body is chilled and the circulation is affected. Susceptibility to

infection of the respiratory tract is thus increased, and the muscles which have been exercised tend to become stiff and sore. In cooling off after exertion associated with much sweating, it is therefore advisable to wrap warmly until the sweat has evaporated or to wipe the body thoroughly, or best of all to take a shower bath (not prolonged if cold) followed by a brisk rub and dry clothing.

When the temperature of the surrounding air reaches 98° to 99° F., no heat can be lost by the body by conduction or radiation to the air. The control of temperature then depends entirely upon evaporation. At temperatures even approaching this height, when the air is saturated with moisture (relative humidity 100 per cent), the body cannot cool by either of its physical mechanisms; the temperature then rises, for the body has no power to suppress its heat production. The reverse of chemical regulation does not occur. The metabolism is not diminished as a result of rise in temperature as it is increased for a fall in temperature; but instead it is augmented, according to the principle of chemistry that reactions are accelerated with rise of temperature. Under hot surroundings there is a disinclination to any exertion; but if exertion is forced, the temperature of the body is markedly and even dangerously elevated.

Accessory Heat Losses.

The amount of heat lost through eating and drinking foods and liquids at temperatures lower than that of the body is under voluntary control. It is only a small percentage of the total heat loss. Iced drinks and chilled foods are welcome when the surrounding temperature is high. Furthermore, greater perspiration as the result of warm surroundings makes possible a greater ingestion of cold water. In cold surroundings hot drinks tend to conserve heat, or even add an appreciable amount.

The amount of heat lost in the expired air varies with the volume of air breathed and with the temperature and humidity of the air. The relative dryness of the air is a more important factor than the temperature of the air. Thus, as pointed out in the section dealing with head colds, the amount of heat used in warming and moistening the dry air of heated rooms is only

slightly less than that required to heat and moisten the cold air of outdoors in severe winter weather.

Fat in Relation to Heat Loss.

A layer of fat envelopes the tissues of the body and separates them from the skin. The thickness of this layer varies in different individuals and in different parts of the body. Fat serves as a heat-insulating material. Although it has only one-ninth the insulating value of air, it nevertheless has three times the insulating value of water. Most of the tissues of the body other than fat are composed largely of water and their conductivity is comparatively high.

Although the main area for the dissipation of heat from the blood is in the skin outside of the layer of fat, yet some heat reaches the skin by conduction through the layer of fat and is added to that brought to the skin by the blood. This heat brought by conduction is not directly subject to control as is the heat brought in the blood. Therefore, a deposit of fat either excessively heavy or excessively thin has disadvantages at the extremes of temperature. Obese men are able to withstand cold better than are lean men. In aquatic animals, such as seals and whales, living in Arctic waters, the layer of fat beneath the skin is extremely thick and forms an important barrier to the loss of heat. These animals maintain a normal temperature in the interior of their bodies while surrounded by a medium which has more than twenty times the heat-conducting power of air, and is at, or even below, 32° F. Although the lean man usually fares better than the fat man in warm surroundings, there is one exception to this. Under the rare conditions in which the temperature and humidity are such that heat cannot be dissipated from the body, the obese man has somewhat the advantage; his greater bulk of inactive tissue allows a slower rise of body temperature and his greater storage of water delays the dehydration of his tissues by sweating.

Clothing in Relation to Heat Loss.

Heat production in the resting state is not sufficient to balance the minimum heat loss from the naked body during complete

rest, if the surrounding temperature is below 80° F. The humidity of the air, the velocity of the wind, and to some extent the hardiness of the individual determine this minimal surrounding temperature below which chemical regulation must be called into play. During exercise much lower temperatures can be tolerated without excessive loss of heat. During swimming, for example, the temperature is maintained by the extra heat production of the exertion, although the naked body may be immersed in water at a temperature of 60° F. or even colder.

Clothing diminishes the heat loss and forms an important factor in the regulation of the temperature in man. In temperate climates we largely remove the necessity for chemical regulation by keeping the skin covered. Only about 20 per cent of the surface is normally exposed to the air; the remainder is maintained at a tropical temperature by the layer of clothing. A thermometer placed beneath the clothing of a person who is comfortably warm registers only a few degrees below body temperature; a similar temperature is found beneath the bed covering at night. Each individual thus maintains about the greater part of his body his own "private climate," which, moreover, is a tropical climate. Even the Eskimo, dressed in furs, lives for the most part in this tropical climate. The fur on animals and the feathers on birds are analogous to the clothing of man.

The insulating property of clothing is largely determined by the amount of air which is held in the interstices of the fabric. If it were possible to surround the body with a layer of air held stationary, better protection would be afforded than by any other material. Furs, feathers, and most porous materials are poor conductors of heat, because of the relatively great amount of air which they enmesh. Fur consists of approximately 98 per cent of air by volume, so that fur really consists of air with some 2 per cent of hair. Similar relations in varying degrees hold for other materials. The following table gives the coefficients of conductivity of some common clothing materials. The coefficient of conductivity is expressed as the amount of heat in small calories which, in one minute, will be given off from an area of one square centimeter of the material one centimeter thick when

there is a difference of one degree centigrade in the temperature of the two surfaces.

TABLE IX

CONDUCTIVITY OF SOME CLOTHING MATERIALS

Substance	Coefficient of conductivity
Air	0.0000532
Feathers (eiderdown)	0.0000574
Knitted wool	0.0000650
Smooth silk fabric	0.0000684
Smooth wool fabric	0.0000686
Hair	0.0000763
Smooth cotton fabric	0.0000810
Knitted cotton	0.0001002
Linen	0.0001158

Beasts and birds vary the insulation afforded by their hair or feathers by increasing and decreasing the amount of air retained stationary in the coat. In cold surroundings the hair or feathers are held more erect and the thickness of the layer thus increased. A similar mechanism, although ineffective, exists in man. The minute projections, known as goose flesh, which appear on the skin as a result of chilliness or emotion, are formed by the pull of the muscles attached to and tending to erect the hairs.

A densely woven cloth does not absorb the moisture from the skin; it also prevents ventilation and the evaporation of this moisture. In hot weather porous cloth next to the skin, so as to absorb moisture and permit its ready evaporation, is particularly important. Rubber coats or shoes lack absorption, prevent ventilation, and thus cause the skin to become hot and sodden in warm weather, but clammy in cold weather. If the garment worn next to the skin becomes thoroughly wet the evaporation of sweat in warm surroundings is largely prevented, to the great discomfort of the wearer, while in cold surroundings the heat loss by conductivity through the wet material is greatly facilitated and chilliness results. Wool of open mesh, in varying thickness, is the best material for both underwear and suits for both summer and winter.

Artificial Heating.

So far as heat losses are concerned, artificial heating of the air of buildings serves the same purpose as clothing. The heating cannot be used advantageously to replace clothing entirely, for a temperature suited to the occupant when sedentary would be so warm as greatly to handicap physical exertion. The indoor temperature is merely brought to a point at which the parts of the body ordinarily exposed, such as the hands, are comfortably warm and dry without a protective covering. Clothing and artificial heating of houses diminish heat loss, but are not, strictly speaking, means of regulating body temperature. They are rather to be regarded as methods of conserving heat, so that the chemical regulation of temperature is rendered unnecessary, and the heat loss is reduced to a degree which permits an efficient automatic operation of the physical regulative process. The discussion of indoor temperature is covered in more detail in Chapter XXI, dealing with climate and ventilation.

Disturbance of the Heat Regulation.

A disturbance in the balance between the production of heat and the loss of heat results in an alteration in the temperature of the body. The influence causing the disturbance may be either of external or of internal origin. In a warm and humid atmosphere the temperature of the body may rise because of the inability to lose heat; the temperature is likewise elevated by such toxic substances as bacterial products which disturb the heat-regulating process.

A hot bath causes the temperature to rise, since with the body immersed there is no escape for the heat produced in the body except through the relatively small area of the head and in the expired air. Temperatures as high as 108° F. result from thirty minutes' immersion in water at 110° or 112° F. The temperature falls rapidly on emerging from the bath. Exposure to air at a temperature higher than the body and saturated with water vapor is analogous in its action to immersion in hot water. If muscular exertion is performed in the warm air the effects upon the temperature are exaggerated by the increased heat production in the body.

The harmful effects of warm surroundings do not arise primarily from an elevation of body temperature, but from the strain put upon the heat-regulating process in attempting to prevent this elevation. The ability to withstand the strain thrown upon the heat-regulating process varies greatly in different individuals. Some persons tolerate repeated and prolonged exposure to heat without serious consequences, although during the time of the exposure their physical ability is greatly diminished; other persons, particularly children, succumb readily to excess of heat and may be seriously injured by relatively slight strain upon the regulating mechanism. They may even collapse before their body temperature has become elevated. The necessity for maintaining a large flow of blood through the skin to cool the body throws an added burden upon the heart; individuals with weak or defective hearts are particularly susceptible to excessive heat and collapse when the already overburdened heart fails to carry the added load. Those who are weakened by ill health withstand heat poorly, as do those also who use alcohol habitually.

The more serious manifestations resulting from exposure to heat are heat exhaustion, sunstroke, and heat cramps.

Heat Exhaustion.

Heat exhaustion occurs in the tropics, especially in damp, low-lying regions, in temperate zones during protracted heat waves when the humidity is high, from exposure to humid artificial heat in bakeries and laundries, in the boiler rooms of steamships, and wherever men work under similar conditions. Many persons, who show the milder forms of heat exhaustion during hot weather, become depressed physically and are unable to work or eat. In children this condition is often associated with gastro-intestinal disturbances and with fever. In more serious cases of heat exhaustion, or, as it is usually called, heat prostration, there are giddiness, nausea, and staggering gait; the face becomes pale, the heart beats feebly, and unconsciousness may follow. The skin is clammy with sweat but the temperature of the body is reduced and may be as low as 95° F. When heat exhaustion occurs in otherwise healthy men, as among stokers, recovery is

usually rapid; but in less healthy persons the condition often passes into unconsciousness and may end in death.

Sunstroke.

Sunstroke, or thermic fever, occurs as a result of excessive exposure to the direct action of the sun; those who do hard work or otherwise exert themselves, especially if they are warmly clad, are particularly liable. The condition does not arise from the sensible heat of the air alone, but is in part due to the action of the sun's rays, probably through those of radiant heat. The condition varies in severity; in extreme cases it may develop so rapidly that the man falls as though struck on the head and dies in a few minutes. The common form commences with headache and a feeling of depression. The eyesight is usually disturbed, so that everything seen appears colored, usually red. Insensibility follows, brief in mild cases, but in severe cases persisting and even passing into death.

The appearance of a man with sunstroke is distinct from that of a man with heat exhaustion. In the latter the functions of the body and its temperature are decreased, while in sunstroke they are stimulated to a high degree. The man's face is flushed, the skin is hot and dry, the pulse is rapid; the temperature ranges from 107° to 110° F., or even higher. A third or more of those suffering from serious sunstroke die. Recovery may be complete, but in most instances the inability to bear high temperatures persists. Others show later a partial loss of the power to concentrate and a failure of memory, and these symptoms are exaggerated in hot weather.

Heat Cramps.

Heat cramps occur in men who exert themselves in hot surroundings. The condition is especially common among stokers in steamships, in foundry workers, and in workers in hot mines. The cramps occur in the muscles of the legs and arms and often also in the abdomen. Any movement or pressure brings on a paroxysm. The attack may last from twelve to thirty-six hours and for some time afterward the muscles are sore. It is now known that this condition is due to an excessive loss of sodium

chloride in the sweat. Salty drinks and foods are beneficial in preventing and treating it.

Treatment of Heat Exhaustion and Sunstroke.

Heat exhaustion and sunstroke are treated by opposite methods; the one by warmth and stimulation, and the other by cold applications. The man with heat prostration is brought into fresh air and wrapped warmly. If he is conscious he may be given hot coffee. In severe cases where the temperature is markedly reduced a warm bath is beneficial.

For sunstroke it is very important that treatment should be immediate, for when the unconsciousness and fever persist for any length of time the likelihood of recovery is seriously lessened. The man is taken to a shady place and put on his back with his head raised. An effort is then made to reduce his temperature by applying cold water or ice to his bared skin. The water may be dashed over him from a bucket, applied with a hose, or he may be placed in a bath of cold water, until his temperature subsides and consciousness returns.

It is important to note that the unconsciousness resulting from sunstroke is the only form of unconsciousness in which water should be dashed over a man. The application of water as a form of "shock" to revive a man who has fainted, or one who has become unconscious from any cause other than sunstroke, is contrary to correct first-aid treatment. No form of shock is advisable, and particularly not one which wets and thereby chills the victim of any other accident or condition. In sunstroke the application of water is intended not as a shock, but to reduce the temperature.

Fever.

The elevation of body temperature, or fever, which occurs in many diseases is due to a derangement of the heat-regulating center. At the beginning of the fever the blood vessels of the skin contract and diminish the loss of heat. The skin becomes cold and pale, or even bluish. The cooling of the skin produces a chilly sensation, although the body temperature is elevated. At times the chilliness excites the chemical regulating mechanism and shiv-

ering occurs. In some fevers, and particularly in malaria, the shivering is marked and is given the name of ague.

The most common cause of fever is infection; the rise in temperature results presumably from the action of material produced by the bacteria. Infection itself is not essential for the production of fever. Many protein materials injected into the blood cause an elevation in the temperature; thus a high fever follows an injection of milk. Likewise when some of the body's own tissue is killed and absorbed, fever results even though there are no bacteria present in the dead tissue. Thus fever results from the absorption of material from a large burn or from a hemorrhage beneath the surface. The temperature in fever is not as a rule sustained, but tends to fluctuate; the course of the fluctuations is characteristic of certain diseases and thus assists in diagnosing the disease causing the fever. Thus malaria, typhoid, tuberculosis, and other diseases each have their own characteristic temperature charts.

The body tolerates any reasonable elevation of temperature without serious consequences. The fevers of sunstroke which rise to 110° F. and higher exceed the toleration of the body and cause death, but temperatures of such dangerous height are rarely reached in fevers arising from infection. A high fever is regarded as a bad sign in an infectious disease because it indicates a severe infection rather than any danger from the fever itself. There is a belief held by some physicians that the fever in infection tends to combat the disease. Many bacteria grow less rapidly and may even be killed at temperatures a few degrees higher than that of the body. How great a part the fever plays in combating the infection is not known; some efforts have been made to treat disease by artificially inducing a high temperature either by hot baths or by the injection of proteins or drugs into the blood; but no great success has resulted.

The elevation of temperature in fever excites the body's metabolism to more than normal activity. Thus in severe fever the basal metabolism may rise to two or three times the normal level. The increased metabolism involves a greater consumption of the fuel of the tissues, and the man with fever loses weight unless he is fed large quantities of food. A hundred years ago

it was the practice to starve patients with fever and to let them have very little water. They became emaciated and suffered intensely from thirst; the debilitated condition thus induced undoubtedly increased the mortality. Benjamin Franklin remarked at that time that "there was a great deal of difference between a good physician and a poor one, but very little difference between a good one and none at all"; he might have gone further, for in that day no treatment was the best treatment and action based on ignorance is the greatest cause of suffering. To-day with broader knowledge it is the general practice to feed fever patients large quantities of nourishing and easily digested food and to give them all the cool water they will drink.

Subnormal Temperature.

In contrast with fever the temperature may fall below normal in weakened states of the body—*e.g.,* during convalescence from disease. A subnormal temperature occurs in the condition known as collapse, in which all of the functions of the body are depressed. Heat exhaustion is a form of collapse, as is also the shock which occurs after a severe injury or hemorrhage. A man in collapse does not die from the fall in temperature; for this fall is, like the fever in infection, merely an indication of the severity of the condition. The temperature may fall to a very low level, with subsequent recovery. There are instances in which the temperature in men intoxicated with alcohol and exposed to cold weather has fallen as low as 85° to 87° F. without resulting in death.

CHAPTER XXI

EFFECTS OF CLIMATE AND VENTILATION

What Constitutes Bad Air.

The activity of a man is greatly influenced by the atmosphere about him. His activity is limited and discomfort is experienced under certain conditions of the atmosphere. Such effects are particularly noticeable in inclosed places where many persons are present. Three possible causes, all three erroneous, have been suggested for this vitiation of air: (1) that oxygen was abstracted and that the percentage of this constituent fell to a level which was detrimental to comfort and health; (2) that the carbon dioxide exhaled poisoned the air; and (3) that some volatile poison emanated from the body either in the exhaled air or through the skin.

Fallacious Conception of Oxygen Deficiency.

The idea of oxygen deficiency was never very strongly championed. A little calculation serves to dispel it entirely. If ten men were inclosed in an air-tight room ten feet long, ten feet high, and a little over ten feet wide, they could exist for many hours without producing a dangerous depletion of oxygen. The room described contains (in addition to the bulk of their bodies) 1,000 cubic feet of air, and of this 21 per cent, or 210 cubic feet, is oxygen. The average man at rest consumes about half of a cubic foot of oxygen each hour; the ten men would consume five cubic feet in this time. After the men had been in the room eight hours, 40 cubic feet of oxygen would have been abstracted from the air and 170 would remain. Instead of 21 per cent of oxygen there would be 17 per cent. No immediate discomfort results from breathing air in which the oxygen has been reduced to 17 per cent. This percentage is equivalent to the pressure of oxygen normally found in air at a barometric pressure of 615 millimeters, or approximately that of Denver, Colorado, where many invalids go for the sake of the climate. Further-

more, the conditions here described as applying to the ten men in a small room are more rigorous than those which would occur except under such special conditions as inclosure in a metal vault. Rooms constructed of ordinary building material are not air-tight, for the air passes through cracks and even through the pores in plaster walls. In an ordinary room with plastered walls the men could live almost indefinitely without suffering from want of oxygen. If additional evidence is needed it is afforded by such facts as the following: In some mines the percentage of oxygen in the air is deliberately kept down to 17 per cent in the hope of preventing the explosion of coal dust, although this is a crude and unwise method of prevention.

Fallacious Conception of Excess of Carbon Dioxide.

The idea that carbon dioxide from the exhaled air accumulates in the air of rooms and gives to it its detrimental character was disproved more than fifty years ago. Nevertheless, some modern textbooks in the field of heating and ventilation engineering still contain such statements as: "Carbon dioxide is constantly being diffused through the air of rooms, rendering it unfit for use." Carbon dioxide in very high concentrations is indeed an asphyxiant, but just as "water cannot rise above its source," so the body can scarcely produce an asphyxiating concentration of carbon dioxide. Even in the worst ventilated rooms it rarely rises above 0.5 per cent. The air in the lungs normally contains between 5 and 6 per cent of carbon dioxide. The concentration in pure outdoor air is between .03 and .04 per cent. The inhalation of 1 per cent of carbon dioxide is without noticeable effect on a man at rest, although it is noticeable when he works. Two per cent causes only a moderate increase in breathing and in some breweries the concentration in the air was maintained at that level without causing any ill effects. Five per cent of carbon dioxide causes an uncomfortable increase in breathing, and very high concentrations such as are found in silos containing fermenting corn may cause death by asphyxia, but this effect is essentially due to lack of oxygen.

Much that has been said concerning the vitiation of air by the abstraction of oxygen applies equally to the vitiation of air

by the addition of carbon dioxide due to breathing. The percentage of carbon dioxide in the air rises as fast, or nearly as fast (in the proportion of about 0.8:1) as the percentage of oxygen falls; therefore in the extreme example given of the ten men in the small room for eight hours, the carbon dioxide would rise to about 3 per cent.

Fallacious Conception of a Poisonous Emanation from the Body.

Although the idea that carbon dioxide is the principal factor in ventilation is thus disproved, standards of ventilation have even to the present time been based on the amount of carbon dioxide in the air. Carbon dioxide, although not poisonous itself, was long believed to afford a measure of the contamination of the air with a hypothetical noxious organic substance emanating from the occupants of the room. The more carbon dioxide, the more noxious organic matter was supposed to be in the air.

The conception of an organic emanation was a natural development from the ideas of the contagion of disease prevailing before Pasteur established the conception of bacterial infection. When bacteria were unknown many diseases were attributed to bad air, particularly night air. It was believed that the mist or miasma that arose from swamps carried with it malaria, for the part played by the mosquito was unrecognized. When the bubonic plague (the "Black Death") reached London great fires were kept burning in the streets to purify the "bad air" which was supposed to cause the disease. Even in the third quarter of the nineteenth century sewer gas from drain pipes was supposed to cause typhoid fever and scarlet fever; in England the soil pipes are still placed on the outside walls of the houses. The idea of poisonous emanations from the body was suggested also by the odor of fetid breath and unclean skin common in crowded and unventilated rooms. These odors are disgusting, but they are not poisonous. Like the smell from sewers, so-called sewer gas, they are harmful only when they contain a spray of bacteria. Even in 1911 the emanation theory was revived, but only to be disproved. Perhaps the most effective disproof of this belief was a simple experiment conducted in the following manner: A

man was placed in a small air-tight chamber and breathed air from outside through a tube. A second man was placed outside the chamber, but breathed the air from within the chamber through a tube. The man in the chamber became uncomfortable, although he was breathing fresh air; the man outside was entirely comfortable, even though he was breathing the foul air. Even when several men were inclosed and breathed the air of the chamber, they experienced a change from discomfort to comfort when an electric fan was started.

Discomfort Due to Physical Properties of the Air.

Such experiments afford a fundamental demonstration of the modern theory of what constitutes bad air. It is not the chemical nature of the air breathed, but the physical characteristics which make it uncomfortable and injurious. The temperature within the chamber was 75° F. and the humidity 89 per cent, while the air outside the chamber was at a lower temperature and much dryer. When the fan was run the cooling power of the air was assisted by its motion.

Atmospheric conditions exert their effects upon human health and comfort chiefly through their influence upon the dissipation of heat from the surface of the body. Four physical properties of the air are concerned in the cooling power of air: temperature, humidity, velocity or movement of the air, and radiant heat. The last factor has been generally neglected in studies of ventilation. Little is known of the effect of radiant heat other than that it may contribute much to comfort in otherwise cold surroundings, such as the difference between areas shaded from the sun and those exposed, a difference particularly noticeable at high altitudes. Radiant heat appears to stimulate the activity of the skin to a greater extent than does a similar amount of heat gained through conduction.

The body loses heat by radiation, conduction, and evaporation. The amount of heat lost by radiation is determined by the difference in temperature between the skin and surrounding objects. The amount of heat lost by conduction depends both upon the difference in temperature and upon the movement of the air in contact with the skin. The heat lost by evaporation is, to the

extent to which sweat is secreted, dependent upon the humidity of the air and the rate of air movement. The movement of the air greatly influences the loss of heat both by conduction and by evaporation; it replaces both the air warmed by the body with cooler air, and the air moistened by the evaporated sweat with dryer air.

Wet Bulb Thermometer.

The ordinary mercurial thermometer records the temperature of the air; the wet bulb thermometer (described below) gives, in relation to the dry bulb reading, a measure of the humidity of the air, and thus indicates the drying power of the air. By the term "relative humidity" is meant the amount of water vapor which the air holds in relation to the total amount that it is capable of holding at the prevailing temperature. The latter amount is determined by the vapor pressure of water, which in turn is determined by the temperature. The partial pressure of water vapor is the same, and the weight of water is the same, in air of any barometric pressure, high or low, that it would be in water evaporated in a vacuum. At 86° F. the vapor pressure of water is 26 mm., alike at sea level and on a high mountain. Air or vacuum saturated with water at this temperature contains 30 grams of water per cubic meter (1 ounce per 38 cubic feet); at 50° F. the vapor pressure is 9 mm. and the air contains 9.3 grams per cubic meter (.3 oz. in 38 cubic feet). At the two temperatures the air contains widely different amounts of water, but at each temperature it is 100 per cent saturated. If, however, the air at 50° F. is heated to 86° F. without the addition of water, the pressure of water vapor still remains at 9 mm. This air is then capable of evaporating water up to an additional 17 mm. of vapor pressure. The warmer air would not be fully saturated, and its relative saturation or relative humidity would be 34.6 per cent $\left(\frac{9}{9+17} = \frac{9}{26} = .346 = 34.6\right)$. The warm, and now relatively dry, air would therefore evaporate twice as much more.

The wet-bulb thermometer consists of an ordinary mercurial thermometer with the bulb inclosed in a tightly fitting sack of

fabric. The lower end of the fabric extends beyond the bulb and dips into a container of water, thus serving as a wick to keep the cloth about the bulb moist. The evaporation of water from the surface of the cloth over the bulb of the thermometer cools it, so that a temperature is recorded lower than that found with the ordinary dry thermometer. The thermometer should be fanned or swung in the air. When the air is fully saturated with water vapor both thermometers register the same temperature. For lesser amounts of moisture the difference in reading depends upon the humidity. The cooling effects of air upon the body follow the wet bulb much more closely than they do that of the ordinary type of thermometer.

Equivalent Conditions of Temperature, Humidity, and Movement of the Air.

The cooling capacity of the air is determined by the relations of humidity, temperature, and movement. The air maintains the same degree of cooling power so long as the combined effect of these three factors remains unchanged, although the values of the separate factors may vary considerably. Thus a rise in temperature may be counteracted by a suitable increase in the movement of the air or by a decrease in the humidity. Combinations of temperature, humidity, and movement which produce the same cooling effect on the body are called equivalent conditions. A temperature of 70° F., with the air saturated with moisture and stationary, produces the same rate of cooling for the body as do the conditions at a temperature of 89° F. with the air only 15 per cent saturated with moisture and moving 300 feet per minute; these widely different states of the air are therefore physiologically equivalent conditions.

Effective Temperature.

The conception of "effective temperature" is used as the basis for the comparison of equivalent conditions. The air when fully saturated with water and motionless has an effective temperature which is determined solely by the temperature of the air. Thus air at 70° fully saturated and motionless has an effective temperature of 70° F. Any equivalent condition of the air has

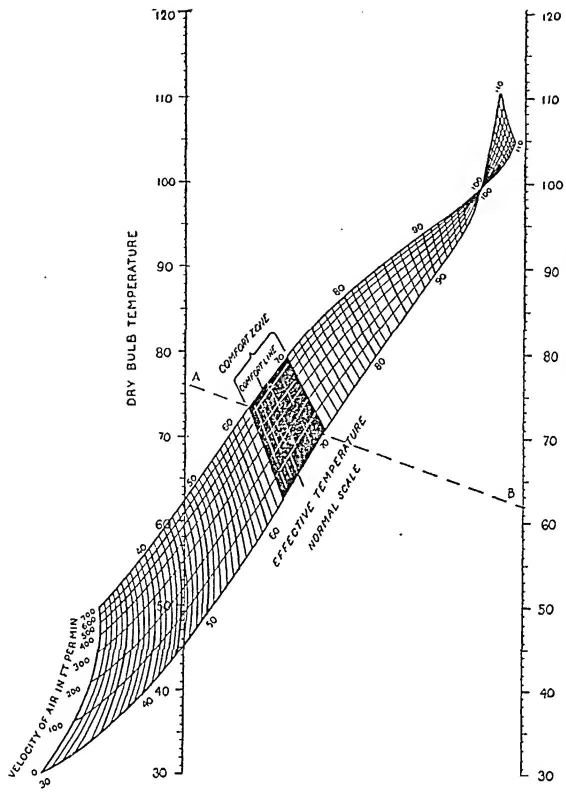


Figure 66. CHART SHOWING EFFECTIVE TEMPERATURE IN RELATION TO WET AND DRY BULB TEMPERATURE AND MOVEMENT OF THE AIR.

Examples in Use of Chart.

Given dry bulb 76°, wet bulb 62°, velocity of air 100 feet per minute, determine: (1) effective temperature of the condition; (2) effective temperature with still air; (3) cooling produced by the movement of the air; (4) velocity necessary to reduce the condition to 66° effective temperature.

(1) Draw line AB through given dry and wet bulb temperatures. Its intersection with the 100-foot velocity curve gives 69° for the effective temperature of the condition.

(2) Follow line AB to the right to its intersection with the 0 velocity line, and read 70.4° for the effective temperature with still air.

(3) The cooling produced by the movement of the air is 70.4° — 69° = 1.4° effective temperature.

(4) Follow line AB to the left until it crosses the 66° effective temperature line. Interpolate velocity value of 340 feet per minute, to which the movement of the air must be increased for maximum comfort.

The comfort zone shown as a shaded area represents the effective temperature to be maintained in dwellings, office buildings, theaters, schools, and other places where only light physical activity is carried on.

In summer when thin clothing is worn the comfort line will approach the lower limit of the shaded zone; with the heavier clothing worn in winter it will approach the higher limit.

also an effective temperature of 70° F. The widely different states of the atmosphere given in the preceding paragraph as equivalent conditions both have effective temperatures of 70° F.

The chart of Figure 66 shows effective temperatures in relation to wet and dry bulb temperatures and movements of the air. This scale was prepared for men wearing ordinary clothing. For men stripped to the waist the effective temperatures here given are several degrees too low; for men clad in heavy clothing such as overcoats, the effective temperatures are high.

Kata-Thermometer.

The so-called kata-thermometer is designed to indicate the effective temperature. This device consists of a pair of thermometers with very large bulbs filled with alcohol and with the stems graduated from 85 to 110° F. The bulb of one of the thermometers is covered with a silk sack. The bulbs are heated in water to about 110° F., and the uncovered bulb is dried. The time taken for the temperatures to fall from 100° F. to 95° F. is then observed with a stop watch. The loss of heat per square centimeter of the bulb is calculated from the mass of fluid in the thermometer, the area of the bulb, and the rate of fall in temperature. The combined influence of temperature, humidity, air movement, and radiant heat are believed to influence the heat loss from the body in much the same way that they do that from the kata-thermometer. A heat loss of 6 millicalories per square centimeter on the dry bulb and 20 on the wet corresponds to a generally comfortable condition for sedentary workers. A greater rate of heat elimination is necessary for those engaged in more energetic occupations.

Influence upon the Body of the Activity of the Heat Regulating Process.

The heat regulation of the body is effected largely through the skin. The skin is an organ of the body just as is the digestive tract; furthermore, the skin is a large organ. Activity of any organ influences the activity of all the other organs of the body. As the activity of one is increased, the activities of the others are in some degree altered. Thus the activity of the digestive tract

after a heavy meal is not an incentive to work or thought, and neither is the activity of the skin when engaged in dissipating heat.

As the cooling power of the air diminishes, an increasing strain is put upon the activity of the skin, in the effort required for the dissipation of heat. The increasing activity of the skin limits the activity of other functions in the body. Under extreme conditions of heat and humidity all the available energy of the body is needed for heat regulation, and outward activity ceases; the consequent depression of bodily functions finds its final expression in the collapse of heat exhaustion. The effort made by the body to dissipate heat in warm surroundings produces fatigue and is a handicap for all physical exertion.

For each degree of muscular activity there is an optimum condition that throws the least strain on heat regulation. Thus climate—and the indoor air in which man lives and works is his climate just as much as the air of outdoors—has a great influence upon human activity, upon the degree of fatigue that arises from this activity, upon health, and even upon civilization, for a high civilization can exist only in an energetic climate.

Influence of Heat Regulation upon the Circulation.

The influence of regulation of temperature upon the activity of other functions of the body is exerted largely through alteration in the distribution of blood. When any organ of the body is active, the flow of blood to that organ is increased. The augmented flow is obtained by the dilation of the vessels supplying the organ. A dilation of the vessels supplying one organ is compensated by constriction of the vessels supplying other organs. Thus an organ which is working carries out its activities at the expense of the blood supply to other organs, and the activities of the latter are curtailed. The curtailment and consequent depression depend upon the size and degree of activity of the organ receiving the augmented blood supply. The increased flow of blood to working muscles results in a diminution of the flow to the abdominal organs. If the exertion is moderate, or only a few muscles are employed, the diminution of blood to

these organs is slight. On the other hand, if the exertion is considerable, as in running, the diminution of blood flow to the abdominal organs is great and their activity is decreased. The nausea sometimes induced by exertion soon after a meal results from a limitation of the flow of the blood to the stomach and intestines.

In cooling the body the skin requires blood for two purposes: to raise its temperature so as to promote heat conduction, and to supply the sweat glands. The secretion of sweat is an active process; as much so as the secretion of saliva or gastric juice. The skin when fully active acts as an enormous gland; five to ten pounds of sweat may be excreted in a few hours.

The constriction of the vessels within the body under hot surroundings does not always compensate for the increased flow of blood demanded by the skin even though the heart beats faster. As a result arterial pressure falls. This fall is particularly marked during the extreme conditions of a hot bath; it is seen in less degree among men employed in cotton mills, where the air is artificially humidified and the temperature high. In heat exhaustion arterial pressure is subnormal.

Influence of Heat Regulation upon Work.

Every hindrance to a free elimination of heat either reduces bodily exertion or causes it to be done under a feeling of oppression and a burden of fatigue. A cool skin not only makes possible a greater muscular exertion; it also increases the desire for the exertion. The following observations illustrate the depressing influence of heat. An increase of room temperature from 68° F. to 75° F., with a humidity of 80 per cent, caused in one test a decrease of 15 per cent in the work performed by men who were stimulated by a cash bonus. Moreover, greater fatigue followed from the lesser work in hot air than from the greater work in cool air. In another test in which the work was performed under conditions of maximum effort, the output diminished 28 per cent under this same elevation of temperature. The curve of output per man for many factories runs at a definitely lower level during hot summer weather.

Stimulation by Local Cooling.

When the entire surface of the skin is heated or cooled it is probable that the flow of blood to all of the organs of the body is altered. On the other hand, heating or cooling the skin over a restricted area induces a response only in the deep structure correlated with that area of the skin. There is a close connection between the nerves which supply the skin and those which supply the deeper structures. An ice pack placed on the skin of the lower abdomen to treat an inflamed appendix does not, and cannot, cool the appendix directly, for a layer of circulating blood intervenes. The vessels of the appendix, however, become constricted because those of the corresponding skin area are constricted by the cold of the pack.

Such reactions in deep structures induced by local changes in the temperature of the skin above them are brought about through nervous reflexes. A change in the temperature of any area of the skin gives rise to impulses which go to the central nervous system. The reception of these impulses alters the activity of the nerve centers and influences their tone. Cold water dashed against the warm skin causes a stimulating and bracing reaction. To a less degree the same effect is produced by variations in the rate of cooling and evaporation due to shifting air currents. The bracing effect of brisk outdoor air in clear weather is due to the movement of the air and to the variations in radiant heat. Indoor conditions of the air are as a rule monotonous and unstimulating from a lack of movement in the air. Lack of motion is the greatest factor in causing the air to feel stale and lifeless. The admission of outside air to heated rooms gives freshness by the motion it imparts to the air in the room rather than by any other alteration.

Movement of the air prevents its stratification. In heated rooms the warmer air rises to the ceiling and the colder falls to the level of the floor. The feet of the occupants are thus immersed in a stratum of cold air and their heads in a stratum of relatively warm air. This most undesirable condition is counteracted when the air is actively mixed by means of a fan or jets of air.

Bacteria in the Air.

Bacteria floating in the air as dust, or in minute droplets of moisture, may contaminate the air and cause infection in those who breathe it. The outside air contains comparatively few bacteria, but in the air of rooms which are occupied the count may rise to seventy or even more in a liter of air. The bacteria in the air of rooms are introduced by the spray of saliva during talking, sneezing, or coughing.

Not all bacteria cause disease, so that the greater number in indoor air is not a direct indication of the injurious nature of the air. Nevertheless, the possible presence of harmful bacteria in public places must be recognized; it is necessary to control ventilation on the assumption that some of the bacteria present are of a harmful variety.

Most air-borne infections require propinquity in order that a sufficiently large amount of the spray of infected saliva may be borne directly from the carrier to infect another victim. Under outdoor conditions people do not crowd as they do indoors, and the movement of air even on the calmest days is large as compared with indoors. The spray of saliva is blown away by the movement of the air, so that the infection cannot be massive, as it may be indoors where the air is comparatively still. Indoor conditions are rendered even worse when the occupants are facing one another at comparatively short distances as they are in a railway or street car or across narrow work benches.

The spread of all air-borne diseases, such as colds, sore throats, bronchitis, and influenza, is promoted by the still and heated air indoors. The observation made on a troop ship may be quoted as an example. Infectious sore throat was ten times as prevalent among the men who occupied three lower decks, which were badly ventilated, as among the men on one upper deck, which was well ventilated. Inadequate ventilation not only permits a greater opportunity for infection, but also increases the susceptibility. Overheating of the air induces congestion of the nasal passages, and this congestion predisposes to infection in that area.

Properly designed ventilation, by renewing the air, diminishes the bacterial count; by creating air movement it scatters the bacteria so that infection is less liable to occur; and by maintain-

ing the air at the proper cooling power it diminishes susceptibility to infection.

Ventilation.

It is generally possible to impart by artificial means a satisfactory cooling power to the indoor air. Such is not the case, however, with outdoor air. Man is the victim of his climate. The dweller in the tropics bears at all times the added burden of keeping himself cool; as this burden limits his activities, he is slow and inert. People of northern countries with their colder and more variable climate are relatively more vigorous, healthy, and ambitious. In history successful invasions of nations have usually occurred from the north, and shifting climatic conditions have influenced the civilization and vigor of entire nations. Even the fluctuations of the seasons in temperate climates have an influence upon the work and health of the inhabitants. The added energy needed to combat heat throws a strain upon the failing forces of those who are ill, and causes mortality peaks to appear after each period of the hot weather in summer.

Recognition of the great importance of the physical properties of the atmosphere upon the activity and health of man opens up many possibilities of industrial betterment. Much improvement has been made recently in the ventilation of factories, offices, and houses, but much more remains to be done. The improvement from the conditions in the middle of the last century may be realized best from an example of factory ventilation as described in 1842, presenting the condition of tailors' work in London at that time: "Eighty men in a room fifty feet long by twenty wide, lighted by a skylight, sitting nearly knee to knee, with an atmosphere in summer 20° higher than outside, and the perspiration so running from them as to spoil, at times, the clothes they worked at; while in winter things were even worse, and in the very coldest nights thick tallow candles melted and fell over from the heat. Men fainted at their work and few men there reached the age of fifty years."

Requirements of Ventilation.

The end to be attained by ventilation is to maintain an atmosphere that conforms to the following conditions:

(1) Sufficiently warm for comfort, thus obviating the chemical regulation of temperature.
(2) Of sufficient cooling power, as determined by temperature, humidity, and movement, for free and efficient working of the heat-regulating process.
(3) Of sufficient movement to be bracing.
(4) Sufficiently renewed to maintain a low bacterial content and to minimize the spread of infection.

Methods of Ventilation.

The most difficult to fulfill of the requirements of ventilation is the important one of air movement, not so much mass movement as mixing and little puffs of air this way and that. Most systems of ventilation are designed to regulate the admission of air from out-of-doors and to obtain some degree of circulation in the air, while fulfilling more or less well the other desiderata tabulated above. The admission of air from out-of-doors serves as the simplest method of imparting movement to the air and at the same time effecting the flushing necessary to keep the bacterial count at a low level. The momentum is imparted to the air admitted through ducts or windows either by the natural movement of the air in passing between zones of different temperature or by such mechanical means as fans which force air into or exhaust it from the room.

The ventilation by the natural movements of the air, that is by windows, is more effective in small rooms than in large ones. The ventilation comes from the exposed walls, and small rooms possess a greater area of wall surface in proportion to their capacity than do large rooms; the surface varies as the square, and the capacity as the cube, of any corresponding linear dimension. When there are no special openings for incoming air, it gains access at poorly fitting sashes or under doors. Even when these cracks are tightly closed a certain amount of air will come through the plastered walls. Flues of fireplaces act as ventilating shafts, and their efficiency is greatly increased when a fire is burning. Windows, even when shut, give some movement to the air. Warm air coming in contact with the glass kept cool by outside air is itself cooled, becomes heavier, and falls to the floor. This

type of movement, although freshening the air, has the objection of contributing to stratification.

Large rooms, particularly those of modern construction with tightly fitting window sashes and asphalt roofs, require special openings for the admission of air. The fact that these rooms often afford a large amount of air space per occupant does not materially improve the ventilation as a whole. Ventilation is, save in the aspect of bacterial contamination, largely independent of the air space allotted to each occupant.

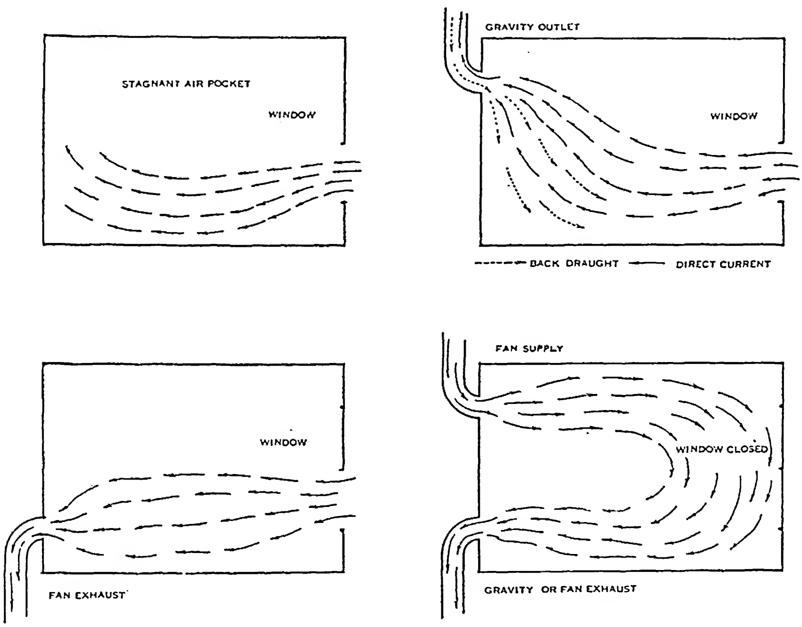


Figure 67. Diagram Illustrating System of Ventilation Discussed in Text.

The various methods of admitting air to effect ventilation are illustrated in Figure 67. Diagram 1 of this figure shows a room ventilated by means of an open window, but with no other outlet for the air. Such ventilation leaves a large area of stagnant air in the upper half of the room and a layer of cold air on the floor. If the window is open at both top and bottom a circulation is induced in the immediate vicinity of the window; the incoming cold air falls to the floor and heated air is forced out of the top

of the window. This condition is not conducive to the comfort of the occupants of the room. If radiators are located immediately beneath the windows, and the windows are fitted with deflectors, the incoming air is heated, rises, and is short-circuited through the top of the window without sweeping effectively through the room.

In diagram 2 an exhaust duct is added in the wall opposite the window. A channel is thus afforded for the air to escape and the incoming air sweeps across the room. The air circulation is varied by wind pressure. If the wind is blowing toward the open window the circulation is augmented. If the wind force is in the opposite direction the circulation is slowed. The pressure and direction may be such as to cause a flow of air down the duct and into the room. This method of ventilation is thus subject to variations induced by the weather, and requires constant attention in order to afford satisfactory results, but with such attention good results may be attained.

In diagram 3 a suction fan is introduced into the exhaust duct to insure circulation. The addition of the fan does not prevent variation in the air flow as a result of variation in the wind; it does, however, prevent back drafts and the lowering of the air flow below a certain minimum. It has the disadvantage of frequently causing a short circuit in the general air flow and in the floor drafts, particularly if the exhaust opening is located at the floor level and if there are inlets in the outer wall at the floor level as in the direct-indirect heating system.

In diagram 4 the air supply is forced by a fan into the room through an inlet near the ceiling. The air stream passes across the room above the heads of the occupants. Air is exhausted from the room with or without the aid of a fan through a duct at floor level and on the same wall as the inlet. As the fan pressure is usually higher than the air pressure acting on the windows, there is a greater tendency for air to leak out of the room than into it.

A saving of fuel for heating can be effected by recirculating the air in such a system as that shown in diagram 4. The air drawn from the exhaust duct is washed by a water spray to remove the greater part of the bacteria and dust; the temperature is

adjusted and the air, generally with the addition of some outside air, is then passed through the fan and into the inlet duct. This system has the advantage of permitting cooling in hot weather.

In the so-called Gerdes system of ventilation, heat is supplied by radiators about the room and the movement and replacement of air are effected by small jets of cold air blown in under pressure from the ceiling. By this method the air is so well mixed that its temperature is uniform from floor to ceiling.

Localized ventilation is employed as an accessory to general ventilation when the latter is insufficient to bring the cooling power of the air to the necessary level. The added cooling power is given to the air by increasing its motion with fans. The fans are used either to increase the movement of the air throughout the entire room or to blow a blast directly upon the worker.

CHAPTER XXII

REPRODUCTION AND THE ORGANS OF SEX

THE essential process in reproduction is the union of a male cell, or spermatozoon, with the female cell, or ovum. The new cell formed by this union divides into two cells, then into four, eight, sixteen, and so on. These cells then differentiate into the various tissues of the body, and the result is an organism which is a replica of its parents.

Fundamentally, the process of sexual reproduction is the same throughout the range of animal life, and for plants as well. The process by which the spermatozoon is enabled to reach the ovum varies in different classes of animals. The protection afforded the fertilized ovum likewise varies in character and duration. But these variations do not alter the fundamental character of reproduction.

Reproduction in man and in the fish is the same process, but the accessory arrangements by which it is accomplished are widely different. In the fish reproduction is effected without bodily contact between the male and female. The female fish discharges her eggs into the water or deposits them on the bottom; the male fish merely ejects his spermatozoa in the water in the neighborhood of the eggs. Each spermatozoon swims about until, if successful, it comes in contact with an egg. Then the essential act of reproduction takes place by the union of these elements. The egg of the fish contains a store of food sufficient to feed the newly formed cell until it has developed into a small fish capable of finding its own food. In the human species the spermatozoa of the male are injected into a cavity in the body of the female. The spermatozoa swim in the film of fluid on the moist surface of this cavity, until one of them reaches the egg deposited in a passage or chamber opening into this cavity. Then the essential act of reproduction takes place by the union of the spermatozoon and ovum. Unlike fish and birds, the human

egg does not contain sufficient nourishment to allow the full development of the newly formed cell. Therefore, the cell remains as a parasite in the mother until it has developed into a child.

Male Reproductive System.

The male reproductive system consists of the testicles, in which the spermatozoa are formed, and an apparatus for conveying and ejecting the fluid semen containing the spermatozoa. From the testicles the spermatozoa pass through a tube, the vas deferens,

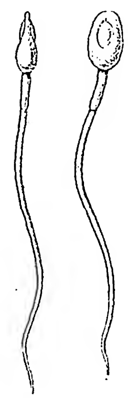


Figure 68. Human Spermatozoon, Side and Front View.

leading to small sacs located beneath the bladder. The spermatozoa are stored in these sacs, or seminal vesicles, until they are to be ejected. At that time they are squeezed from the sacs into the urethra in the base of the penis; further volume is added by secretion from the prostate gland. The collected material, or semen, is then ejected by a muscle which squeezes down upon the urethra.

The Testicles.

The testicles are ellipsoid in shape and measure approximately one and a half inches in length and three-quarters of an inch in thickness. They are suspended beneath the pelvis in a pouch called the scrotum. The testicles do not develop in this position. They are formed in the abdominal cavity just below the kidneys, and descend from there into the scrotum. The descent is usually completed about two months before birth. In the final portion of

this descent the testicles carry the peritoneum ahead of them and pass through the inguinal rings, the anatomy of which has been discussed under hernia.

One or both of the testicles may be stopped in their descent, usually in the inguinal canal, and fail to reach the scrotum. In some animals, such as the elephant, the testicles do not descend, but remain throughout life as abdominal organs; in others, such

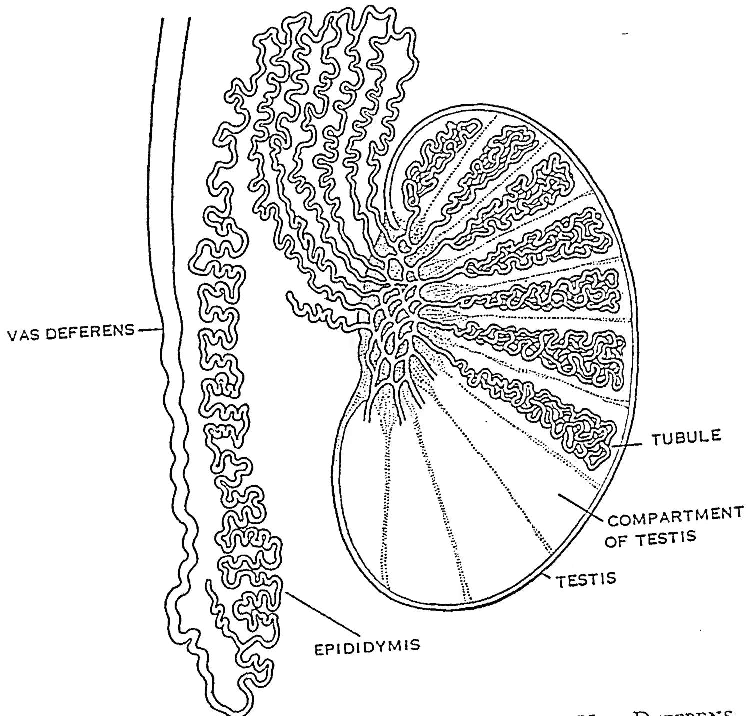


Figure 69. Section of Testis, Epididymis, and Vas Deferens.

as the rat, the pouches of peritoneum which surround each testicle fail to close in the inguinal canal, and the testicles may be drawn at will through the opening into the abdomen, probably a protective measure in fighting.

The testicle consists of a capsule of strong elastic tissue, the interior of which is divided into numerous compartments by partitions of the same tissue. Long, branching, convoluted tubes fill these compartments. The spermatozoa are formed within these tubes. The cells which line the tubes go through a series

of alterations culminating in the formation of the spermatozoa. This process consists in the division of the cells in such a manner that the chromosomes are reduced to one-half the number normal to human cells. The chromatin is gathered together into a mass similar in shape to a blunt arrowhead. This mass is essentially the nucleus of a cell; in fact, the spermatozoon is a cell. Around this nucleus there is the minimum of cellular material, except that on one side a long slender tail is formed. This tail

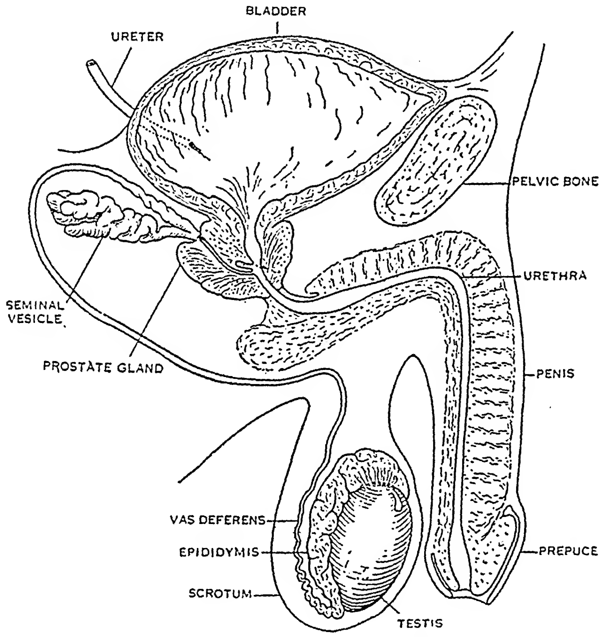


Figure 70. SCHEMA OF MALE REPRODUCTIVE SYSTEM.

is the organ of locomotion for the spermatozoon; it plays no part in reproduction other than to give to the spermatozoon the motility which enables it to reach the ovum. When the ovum is reached, the mass of chromatin forming the head of the spermatozoon enters and unites with the nucleus of the ovum. The tail, having performed its function, is dropped off.

The Epididymis, Vas Deferens, and Seminal Vesicles.

The convoluted tubules which fill the compartments of the testicle, open into a common tube which emerges near the top of

the testicle. This tube is several feet long but is convoluted to such an extent that it is compressed into a small pouch attached to the testicle. This pouch and its tube are known as the epididymis. On emerging from the epididymis the tube becomes larger and firmer, and is then known as the vas deferens. As the spermatozoa mature in the testicle, they pass along the convoluted tubules into the common tube making up the epididymis, and from there into the vas deferens.

The vas deferens is about an eighth of an inch in diameter and twelve inches long. It extends from the epididymis to the urethral canal of the penis. In its course the vas deferens goes through the inguinal canal and enters the abdominal cavity. It can be felt on either side of the center of the body as a firm cord passing over the pelvic bone near the external inguinal rings. At this point in its course it passes nearest to the surface of the skin and it is here that it is cut in sterilizing a male; the severance of the connection between the testicle and seminal vesicles prevents the passage of spermatozoa, but does not otherwise interfere with sexual activity.

The seminal vesicles are small pouches which open out from the vas deferens just before it enters the urethra. Each seminal vesicle is surrounded by a muscular coat which, by contracting, forces the spermatozoa into the urethral canal. The seminal vesicles lie beneath the bladder and in front of the rectum. The urethra constitutes the remainder of the genital passage in the male. The seminal vesicles open into it through a minute passage near the bladder. Since the urethra is a passage of the urinary as well as the generative system, the spermatozoa are brought into it only when they are to be discharged.

The number of spermatozoa discharged at one time is enormous—200,000,000 is an approximate figure. Nevertheless, the volume occupied by this great number is minute. The spermatozoa, aside from their delicate tails, are no larger than the red blood corpuscles, 5,000,000 of which occupy less than half the volume of one cubic millimeter of blood. Most of the fluid necessary for the discharge of the spermatozoa is supplied by the secretion of the prostate gland.

The Prostate Gland.

The prostate gland is about the size and general shape of a large chestnut. It is situated at the base of the bladder, and surrounds the urethra. The tube leading from the seminal vesicles to the urethra also passes through it and meets the urethra near the center of the gland. A muscular coat surrounds the gland; when it contracts the viscous secretion is expressed into the urethra.

The fact that the urethra passes through the prostate gland is an unfortunate relation, for any enlargement of the gland tends to constrict the passage. Such an enlargement occurs in about one-third of all men who have passed middle life. Numerous theories have been offered in explanation of this enlargement, but the cause is not known. The constriction of the urethra interferes with urination. The enlargement usually develops slowly; interference with urination follows progressively until in some cases the flow is suppressed and it is necessary to pass a catheter to relieve the bladder. It may then be necessary to remove the prostate gland by a surgical operation.

The Penis.

The penis serves to direct the discharge of the seminal fluids. The human penis consists of three cylindrical-shaped masses of erectile tissue bound together with connective tissue and surrounded by a layer of skin. Erectile tissue has a spongy structure and contains cavernous blood vessels. The pressure of the blood filling these vessels determines the size and firmness of the tissue. Two of the cylinders of erectile tissue forming the penis are attached to the bones of the pelvis. The third cylinder of erectile tissue lies below the other two and in the groove formed by their junction. This lower cylinder of erectile tissue is longer than the other two; it is expanded at each end, in the rear to form a bulb and in front to form a conical cap covering the ends of the two upper cylinders, the head or glans of the penis. The urethra passes through this lower cylinder of erectile tissue.

The urethra is lined with mucous membrane. The skin which covers the penis meets this mucous membrane at the margin of the external opening of the urethra. At the glans of the penis the

skin is turned forward in a fold which surrounds the glans and forms the prepuce, or foreskin. The skin covering the glans and lining the prepuce contains no hairs, but it retains the grease glands which ordinarily accompany the hairs. The secretion of these glands appears as a whitish solid material. If not kept clean, the prepuce becomes irritated by the accumulation of this material. The operation of circumcision consists in the removal of the prepuce. This operation is performed when the opening of the prepuce is contracted and retraction prevented; it is also performed as a ritualistic measure in the Jewish and Mohammedan religions. The seminal vesicles and prostate gland open into the bulb formed at the rear end of the lower cylinder of erectile tissue. This bulb is surrounded by a muscle. When the muscle contracts the bulb is compressed and its contents are discharged through the urethra.

Sexual Activity.

In order to fulfill its function of directing the discharge of the seminal fluids, the penis must become rigid. The flow of blood into the cavernous spaces of the tissue is increased, and at the same time the veins which carry the blood away are probably compressed and partially occluded by muscles extending across them. The erectile tissue is thus filled with blood under considerable pressure, and is distended to the limit permitted by the layer of connective tissue surrounding it. The dilation of the arteries which results in the erection is controlled by nerves from a center near the lower end of the spinal cord. This center is acted upon by sensory impulses arising in the genital tract and by impulses descending from the brain; both mechanical stimulation of the genital tract and emotional excitation can cause erection. The nerves controlling the discharge of the seminal secretions come from centers, like those producing erection, in the lower end of the spinal cord. The discharge is largely a reflex act initiated through the same impulses which bring about erection. Nerves extending from these centers carry impulses to the brain so that ordinarily the act is accompanied by a strong psychic reaction.

Activity in the mechanism of erection and discharge may be initiated by impulses arising from the seminal vesicles and vas

deferens. When these structures are distended by the collection of spermatozoa, discharge is accomplished during sleep by the so-called nocturnal emission. These involuntary discharges do no harm whatever unless they are of unusual frequency (several each night) as the result of irritation of the genital passages. If, as is usually the case, they result merely from the normal filling of the vas deferens and seminal vesicles with spermatozoa, they are entirely healthful. Nevertheless, the manufacturers of some patent medicines and quacks prey upon the ignorance of young men, leading them to believe that these emissions are detrimental to health or, as these false counselors express it, to "manhood." While the emissions are in themselves harmless, the belief that they are harmful actually does harm. The worry which results undermines the young man's confidence in himself as a fit and healthy individual and tends to make him secretive and moody.

What has just been said concerning nocturnal emissions applies likewise to emissions induced through voluntary excitation of the genital tract, the practice of masturbation. From a purely physical aspect this practice when carried to excess (many times daily) is unquestionably detrimental to health, as would be an equal excess of sexual activity in a normal manner. Masturbation is rarely carried to such excesses by the normal and healthy individual. According to older beliefs, still unfortunately very common, a wide range of abnormalities, particularly nervous and mental, result from masturbation. It seems more probable that the actual sequence is reversed and that excessive masturbation, instead of causing these abnormalities, occurs as a result of them. It is an unfortunate practice to impress upon boys the idea that masturbation is ruinous to their health and character. Masturbation should be discouraged, but it is doubtful if the doctrine of moral damnation really attains this end. Rather the character and self-confidence of the young man are hurt by what appears to him his lack of will power in yielding to a practice which he has been taught is shameful. In fact, all men have to learn to control this habit in which practically all adolescent boys indulge to some extent. Irritation of the genital tract due to lack of cleanliness, or from other causes such as overeating, lack of suffi-

cient physical exercise, and erotic stimulation from pictures and plays, are the main excitants to masturbation. Vigorous, regular, physical exercise, mental activity, and a simple diet are excellent deterrents.

Sexual excitement is a physical as well as an emotional state, and the extent to which the body expends its energies through sexual channels depends in great measure upon the extent to which energy is expended through other channels. The energy which might be dissipated through sexual activity may be diverted—"sublimated," as it is called—into other activities. In the preceding paragraph physical exertion was. suggested as an outlet, or sublimation, of sexual activity; mental activity serves the same purpose. By a reversal of this process, excessive sexual activity may usurp energies which might have been directed into other channels. It seems probable that the rate at which the testicles produce spermatozoa is influenced by the energy available for expenditure by the generative system. Sublimation of the sexual emotion may result in a slower filling of the seminal vesicles and in a retardation of the excitement arising from them. It is the sublimation of the male sexual energy which produces the emulative spirit and mental activity that characterize successful men in all vocations. This is true alike of the great soldier, preacher, lawyer, or business man. This sublimation is impaired when the mind is filled with erotic imaginings by means of "smutty" stories, pictures, and conversation.

The Female Reproductive System.

The female reproductive system consists of the ovaries in which the ova are formed, a cavity, the vagina, for receiving the spermatozoa from the male and conveying it to the ovum, and a chamber, the uterus, in which the fertilized ovum is retained and nourished until it has developed into a child.

The Ovaries.

The ovaries are of the size and shape of large almonds. They are suspended within the abdominal cavity by a ligament attached to the uterus. The position of the right ovary, as judged from the anterior surface of the abdomen. is close to the appendix;

the left ovary is correspondingly placed on the opposite side. The ovaries are analogous to the testicles of the male. In contrast to the vast number of spermatozoa produced the ovaries develop only about 400 mature ova during an entire lifetime, that is, one ovum for each lunar month from the fifteenth to the forty-fifth year. Small elevations resembling blisters appear on the surface

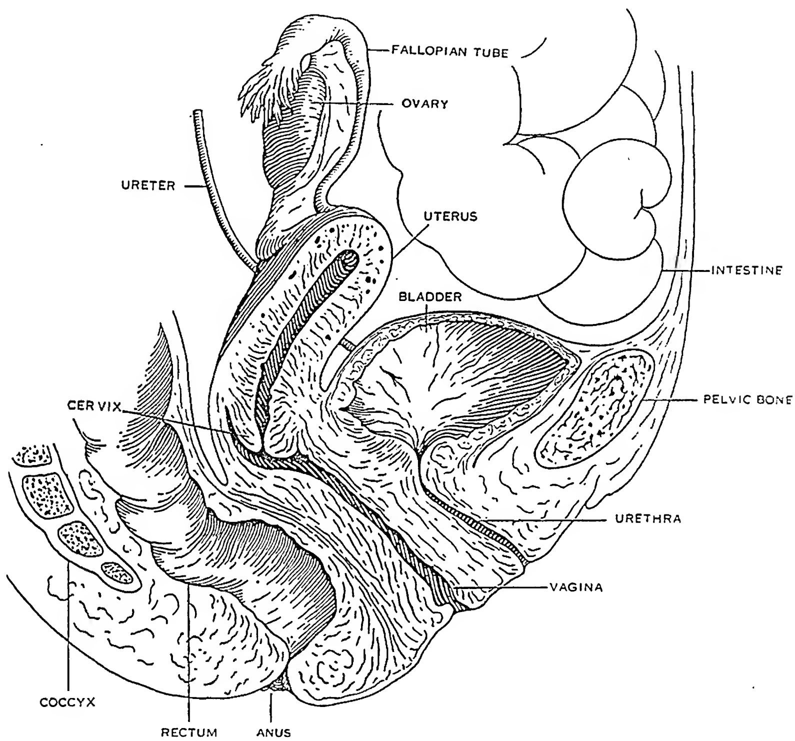


Figure 71. Schema of Female Reproductive System.

of the human ovary as each ovum matures. The ovum is suspended in the fluid of the blister and when the membrane ruptures the ovum is discharged into the abdominal cavity.

The ovum, like the spermatozoon, contains only one-half the number of chromosomes characteristic of the human cell. This mass of chromatin is surrounded by a layer of nutrient material, the ovum thus formed being a sphere about 0.2 mm. (0.004 inches) in diameter. A much greater supply of nutrient material surrounds the chromatin in the ova of animals which do not bear

their young. The chromatin in the egg of the hen, for example, is no larger in size than that in the human egg; the greater bulk of the egg is made up of food necessary to sustain the developing embryo until the chick breaks from the shell.

Fallopian Tubes.

The ovum is discharged from the ovary into the abdominal cavity. From there it passes into one of the two Fallopian tubes. These tubes are analogous to the vas deferens of the male, for they are passages through which the sex cells are conveyed. The Fallopian tubes are held in the upper border of the broad ligament which extends from the sides of the uterus to the lateral walls of the pelvis; the ovaries are in contact with the rear surface of this ligament. The Fallopian tubes extend laterally from the upper corners of the uterus; the expanded outer end of each tube is cupped directly over one of the ovaries, the lower ends open into the uterus.

The inner surface of the tubes is lined with mucous membrane which is covered with minute hair-like projections called cilia. The mucous membrane of the upper respiratory tract is similarly equipped with cilia which, by their waving motion, carry dust particles out of the respiratory tract. In like manner the cilia of the Fallopian tubes create a current toward the cavity of the uterus, which draws the ovum discharged from the ovary into the tube, and propels it toward the uterus. If spermatozoa are present in the Fallopian tubes, one of them may unite with the ovum during its passage. The fertilized ovum then passes to the uterus, where it remains for the completion of its development. If spermatozoa are not present, the ovum continues its passage into the uterus without being fertilized, and is carried from the body with the next menstrual discharge.

The Vagina.

The vagina forms the cavity for the reception of the semen and the spermatozoa contained in it. It is a tubular structure opening at the surface of the body and extending inward to the uterus. The external opening is situated between the urethral outlet and the anus in a position similar to that occupied by the

scrotum in the male. The vagina lies in the space between the bladder and the rectum. Folds of flesh called labia, arising from each side of the vaginal entrance, cover it and also the opening of the urethra. In women who have not borne children the entrance of the vagina is partially occluded by an irregular sheet of membrane known as the hymen. The hymen varies greatly in different individuals; in extreme cases the membrane completely closes the vaginal entrance and must be lanced to permit the establishment of the menstrual flow; in other cases it is merely a small fringe of membrane attached to the sides of the vagina. The hymen is usually stretched or torn by coition, but the diversity of its normal structure sometimes precludes the possibility of using it as a test of virginity.

On each side of the vagina, near its entrance, there are glands which are somewhat analogous to the prostate gland in the male. The secretion of these glands serves to moisten the vagina, but it has no function directly connected with the process of fertilization. The vagina and uterus, like the Fallopian tubes, are lined with mucous membrane.

The Uterus.

The uterus, or womb, is a contracted muscular bulb. It is shaped like a pear and is held with the large end uppermost. The tapering lower end, or cervix, as it is called, projects a short distance into the inner end of the vagina. The Fallopian tubes extend from the sides of the upper part of the uterus. A small canal passes from the cavity of the uterus through the cervic and opens into the vagina. The Fallopian tubes, the cavity of the uterus, the canal of the cervix, and the vagina form a continuous passage extending from the ovaries to the surface of the body. The size of the uterus is variable. In women who have not borne children it measures 5.5 to 8 cm. (2 to 3 inches) in length and 3.5 to 4.0 cm. (less than 2 inches) in breadth at its widest point. In women who have borne children the uterus is somewhat larger. The cavity of the uterus is merely a cleft, but during pregnancy it is distended to hold the developing fetus, its attachments, and the fluid in which it floats; at this time the walls of the uterus are stretched thin.

The uterus lies between the bladder and rectum except during pregnancy, when the upper surface rises far above this level. It is not fixed rigidly in place, but is suspended from ligaments. Normally the upper end of the uterus tips forward and rests upon the bladder. Occasionally the uterus is displaced from its normal position and bends backward, or to one side, or even descends for some distance into the vagina. These displacements are sometimes the cause of sterility. They may also give rise to disturbances from pressure upon the bladder or rectum or from the pull upon the ligaments. They interfere with menstruation and render it painful. Although displacements may occur in women who have never borne children, they arise more often during the first two months following the bearing of a child. The uterus at this time is large, its muscle flabby, and the ligaments are stretched and relaxed.

Menstruation.

The periodic discharge of blood from the uterus is known as menstruation. The commencement of menstruation marks the attainment of sexual maturity or puberty in the female. The average age in the temperature zone is the fourteenth or fifteenth year. In races native to warm countries the age of puberty is earlier, while in races native to cold countries it is later. Race, rather than climate, is the determining factor; the time of puberty characteristic of a race is maintained even after generations of residence in countries of a different climate, a fact that is illustrated by the early appearance of menstruation in the Jewess even in cold countries.

Menstruation, after it is established, continues at regular periods, usually of twenty-eight days. It is not absolutely regular, and periods of twenty to thirty-five days are within the normal range. Premonitory symptoms, such as pains in the back and head, and general discomfort commonly precede the appearance of each menstrual period; in some cases the flow is accompanied by severe pain. The discharge continues three to five days.

Normal menstruation continues, except during periods of pregnancy and lactation, until the menopause. In the temperate zone the menopause, or climacteric, usually occurs about the fiftieth

year, although it is occasionally delayed until the sixtieth. The age at which it occurs, like that of puberty, is a racial characteristic; it is earlier in the natives of hot than of cold countries. The change is sometimes abrupt and sometimes gradual, being preceded by irregularities in menstruation. The period of the menopause is sometimes associated with serious mental disturbances.

Menstruation may be suppressed during severe illness, from worry, grief, or exhaustion from hard work. Chilling the body or even wetting the feet during the time of menstruation may stop the flow and render it irregular and painful for some time afterwards. The menstrual flow is usually greater in warm weather than in cold. Tropical climate induces such excessive and prolonged menstruation in some white women that they become anemic.

When menstruation is painful it is a handicap to the woman in employment. In extreme cases she may be forced to remain in bed for a day at the beginning of each menstruation. More often the pains can be relieved. Some shops and factories have found it expedient to give their female employees treatment at the plant rather than to allow time off for difficult menstruation. The woman suffering from menstrual pains reports to a nurse, who has her lie on a couch, loosens her clothing, and administers a warm drink and a sedative. After resting with a hot water bottle on her abdomen for twenty minutes to a half hour, the woman is usually relieved to an extent sufficient to allow her to return to work.

Menstruation is one phase of a cyclic process. Approximately five days before the appearance of the discharge the mucous membrane of the uterus becomes congested and swollen. When the process reaches its maximum the surface bleeds and the menstrual flow is produced. In the week following menstruation the congestion diminishes, and finally disappears; any mucous membrane which has been destroyed then grows anew. During the twelve days remaining in the cycle of twenty-eight, the uterus is in a state of rest.

Many theories have been advanced to explain the significance of menstruation, and of these two have persisted. According to

one theory the cyclic process of which menstruation is a part occurs in order that the mucous membrane of the uterus may be kept in an active state so that the fertilized ovum will find a receptive surface for its attachment. According to the other theory, the uterus reacts each month as if fertilization of the ovum had occurred, and begins the changes incident to the implantation of the ovum on the mucous membrane. If fertilization has not taken place these changes are brought to an end in the discharge of the accumulated material and the repair of the mucous membrane. According to this view menstruation occurs because conception has not taken place.

Menstruation is not essential to impregnation. Many women have become pregnant before they started to menstruate, or during the time when they were nursing a child and had ceased to menstruate for that reason, or even after the menopause. In one instance recorded in the literature a woman, who was married before menstruation had commenced, did not menstruate until she was nearly forty, for during this entire time she was either pregnant or nursing a child.

Ovulation.

The occurrence of the menstrual cycle is dependent upon an internal secretion of the ovaries. When the ovaries are removed menstruation ceases; but it is reëstablished if the ovaries are successfully grafted into some tissue of the body. The internal secretion which initiates the menstrual cycle usually passes into the blood a short time before the ovum escapes from the ovary on its way into the Fallopian tubes. Ovulation thus occurs in the majority of cases at approximately the same time as menstruation; but this relation is not always maintained, and ovulation may occur at any time during the menstrual cycle, and it may continue even though menstruation is suppressed.

Migration of the Spermatozoa.

The spermatozoa are deposited in the vagina near the opening of the cervix of the uterus. They travel from this point through the uterus and up the Fallopian tubes by means of their own motility. The spermatozoa are guided in this course by the opposing

current on the surface of the mucous membrane of the uterus and tubes. The cilia on these surfaces create a current which propels immotile particles, such as the ovum, toward the cervix of the uterus. The spermatozoa are so constituted that they swim against the current and are thus guided by it.

Fertilization.

The ovum and spermatozoon, like all other living cells, contain a number of small bodies which, because they can be stained by certain dyes, are known as chromosomes. In each species of animal a definite number of these bodies appears in all the cells, but in different species there may be a different number. These chromosomes are considered the bearers of heredity. Each has within it certain particles which determine some quality or characteristic of inheritance. In the process of growth, the cells multiply in number by dividing; in this division the chromosomes are split longitudinally and the normal number thus goes to each daughter cell. In the formation of the spermatozoon and ovum, however, a different type of division takes place; the chromosomes are divided numerically so that the completed ovum and spermatozoon each contain only half the number of chromosomes characteristic of the species. Furthermore, in this division each cell loses part of the material necessary for the normal division and growth. Thus the spermatozoon and ovum are basically only half cells; each is the complement of the other. The full number of chromosomes and the material necessary to initiate the process of cell division and growth are restored by their union. The chromosomes of the new cell thus formed are derived equally from each parent; they bear the blended hereditary characteristics of both.

In the process of fertilization a single spermatozoon penetrates the ovum; in so doing it stimulates the ovum to form a membrane over its surface which prevents the entrance of additional spermatozoa. With the full equipment necessary for division restored by this union, cell division and growth are initiated. The growing mass of cells is carried slowly toward the uterus by the cilia of the mucous membrane lining the Fallopian tube. During this time the mucous membrane of the uterus becomes thickened

and congested in preparation for the reception of the ovum. When the developing ovum reaches the uterus it secretes a digestive fluid which erodes a minute opening in the mucous membrane into which the ovum enters. The mucous membrane then closes over the ovum.

Development of the Ovum.

The microscopic mass of undifferentiated cells, now parasitic upon the mother, slowly develops into the fully formed infant. As the first step in this development fluid is formed in the center of the minute mass, until the cells constitute a shell about the collection of fluid. Next the three fundamental tissues of the body are differentiated as three layers of cells in the shell. The inner layer of cells is called the endoderm, the middle layer the mesoderm, and the outer layer the ectoderm. Each is the progenitor of a group of tissues in the human body; each retains throughout life much the same position as that which it occupied in its initial development. The covering of ectoderm forms the skin, hair, and nails. The endoderm forms the lining of the alimentary tract and the glands which extend from it. The middle layer, or mesoderm, forms the tissues and structures which lie between the outer and inner layer—the bones, muscles, tendons, and the circulatory system. The nervous system forms an exception to the original distribution of the tissues, for it arises from the ectoderm just as the skin does. The primitive nervous system starts as a groove on the surface, but the sides of this groove rise and fold over, thus inclosing a part of the ectoderm within the mesoderm. This buried column of cells continues as the brain and spinal cord, and its offshoots become the nerves.

On the side of the ovum which is buried deepest in the wall of the uterus, the cells multiply more rapidly than do the others; an inner mass is thus formed which projects a little way into the fluid filling the ovum at this stage. A space filled with fluid forms within the center of this mass. As the opening increases in size it pushes its way through the middle layer or mesoderm, until finally it has nearly completed the circuit of the inside of the ovum. What remains of the inner mass of cells is thus left hanging within this space and is attached to the inner wall of the

shell by a stalk. The mass of cells thus suspended is known as the embryo. Ultimately it grows into the child. The stalk which forms the attachment to the wall of the ovum becomes the umbilical cord; and the covering of the space filled with fluid forms the membrane within which the child is developed. At birth this sac is ruptured, its fluid is discharged, and the child passes through the rent in the wall.

Formation of the Cord and Placenta.

The nourishment for the growth of the ovum and its embryo is derived from the mother. Small projections extend out from the walls of the ovum and burrow into the tissue of the uterus. The tips of these projections erode the blood vessels, and blood escapes into little pools in the muscular wall of the uterus. The tips of the processes dip into this blood and absorb from it food and return wastes. At the end of the first month after its implantation, the ovum, which by this time has reached a diameter of nearly two inches, is completely covered with these processes which appear like moss.

When the blood and blood vessels form in the embryo, the vessels extend out along the stalk by which it is attached to the inner wall of the ovum. They continue out into the processes which have burrowed into the vessels in the wall of the uterus. The blood vessels of the developing child are now brought close to those of the mother. There is a free and active diffusion of dissolved food and waste through the membrane between the blood of the child and that of the mother. These two blood streams are always separated by the walls of the child's vessels; the child's blood and the mother's blood never mix.

As the ovum grows it expands into the cavity of the uterus. The inner wall of the uterus which has closed over the implanted ovum is stretched and becomes thin; in consequence its supply of circulating blood is diminished. The projections on the surface of the ovum gradually shrink and finally disappear over this area, but they remain in the part most deeply buried in the uterus, which in the ovum corresponds to the region of the stalk holding the embryo. The fleshy growth formed by these remaining projections and their blood vessels is known as the placenta. The

stalk holding the blood vessels extending to the embryo or, as it is called later in the development, the umbilical cord, is attached to the center of the placenta.

The placenta forms at whatever point in the uterus the ovum happens to implant. Usually this implantation occurs in the upper part of the uterus. Occasionally it occurs in the lower part, and the placenta may then in its growth cover the opening of the cervix. This condition of "placenta previa" may lead to serious hemorrhage during, or even before, the birth of the child. Normally the placenta remains attached to the wall of the uterus until after the child is born. A continuance of the uterine contractions producing what are termed after-pains results in the separation of the placenta from the walls of the uterus. The placenta, together with the ruptured membranes and cord, is then expelled from the uterus, forming the "afterbirth."

Occasionally the ovum is arrested in its passage to the uterus and implants in the Fallopian tube; but a tubal pregnancy cannot develop to full term. Usually the ovum ruptures either into the tube or through its outer wall into the abdominal cavity. Severe cramp-like pains and dangerous hemorrhage result.

Development of the Embryo and Fetus.

During the first two weeks of pregnancy the entire product of conception is known as the ovum. Between the third and fifth weeks the various organs are developed in the mass suspended from the stalk; to it the term embryo is then applied. At this stage the human embryo is closely similar in appearance to that of all other animals. By the end of the fifth week, however, the head has enlarged considerably, owing to the development of the brain, and has some resemblance to the human form. The term fetus is then applied to what was previously called the embryo.

By the end of the second lunar month the fetus has attained a length of 2.5 centimeters (1 inch). During the third month particles of calcium begin to appear in the masses of mesoderm in the structures which are subsequently to become bones. At the end of this month the entire product of conception is about 4 inches in diameter and the fetus measures 7.5 centimeters (3 inches) in length. By the end of the fourth month the fetus is

17 centimeters (7 inches) long and weighs 120 grams (1/4 pound). At this time sexual differentiation is well advanced. During the fifth month the skin becomes less transparent and is covered all over with a downy hair. During the sixth month the fetus attains a length of 25 to 35 centimeters (10 to 14 inches). If born during this period, it will attempt to breathe and moves its limbs; but it dies in a short time. During the seventh month the sebaceous glands about the hairs secrete a white fatty substance which covers the skin, protecting it from the prolonged immersion in the amniotic fluid. The membrane which covers the eyes disappears during the seventh month. A fetus born at this time normally weighs 2,300 grams (5½ pounds). It moves its limbs and cries, but as a rule it cannot be kept alive even with the most expert care. It is popularly believed that a child has a better chance of living if born at the end of the seventh month than at the end of the eighth. This erroneous idea is a remnant of the old Hippocratic doctrine. The more developed the child is the greater are its chances for life. At the end of the tenth month, 280 days, the fetus is fully developed and ready to appear as the newborn child.

The Child at Birth.

At birth the child is 50 to 52 centimeters (20 to 21 inches) in length and weighs on the average 3,250 grams (7¼ pounds). The downy hair has been shed, but the skin is still covered by a greasy coating. The head is usually covered with hair about an inch in length. This hair is dark even in the children of blond parents, and is subsequently shed. The eyes of the newborn baby are always blue.

Although 3,250 grams (7¼ pounds) is given as the average weight of the newborn child, this figure is variable. The weight of perfectly healthy children may range from 2,300 to 5,000 grams (5 to 10¾ pounds). The latter figure is rarely exceeded, nevertheless it is not unusual to hear reports of children weighing 15, 16, and even 20 pounds at birth. The majority of such cases are apocryphal or they are based on estimates rather than accurate measurements. In the records of 30,500 deliveries in one hospital, only five children weighed more than 5,000 grams (10¾

pounds). Premature babies weighing less than 1,500 grams (3¼ pounds) have little chance of life, although in exceptional cases children weighing less than 2 pounds have been successfully raised.

The social conditions of the mother, and therefore her comfort and choice of diet, influence to some extent the size of the child. Heavy children occur more commonly in the well-to-do classes. It is popularly believed that the comparatively difficult labors of the women of the upper classes are due to the enervating influences of civilization and luxury, while the easy labors of colored women and immigrant classes are considered a manifestation of a closer approach to nature. The more probable explanation lies in the difference in the size of the children at birth.

Sex of the Child.

Statistics show that more boys are born than girls; the proportion runs about 106 to 100. This difference can be accounted for in either of two ways: that more boys result from conception, or that boys have a slightly better chance of surviving throughout the period within the uterus than have girls. Until very recently it was believed that sex did not become established until some time after fertilization. It is now recognized, however, that sex is determined at the time of union of the spermatozoon and ovum. The sex-determining factor is believed to be a chromosome which exists in the ovum of some species of animals and in the spermatozoon in other species; in man it is in the spermatozoon. This chromosome does not take part in the reduction of chromatic material occurring during the formation of the spermatozoa and ova, but passes, purely by the laws of chance, into one-half of the spermatozoa, or ova in some species, and is absent from the other half. Its presence results in an individual of one sex; its absence results in the other. Sex is thus determined at fertilization and depends upon the presence or absence of this chromosome in the individual. According to this view the determination of sex is entirely a matter of chance and cannot be controlled.

Numerous attempts, all eventually failures, have been made to influence or even to predict the sex of the unborn child. Since there are only two possibilities, the sex can be predicted with

an accuracy of 50 per cent; the successful predictions are remembered and commented upon, while the unsuccessful predictions are forgotten.

Multiple Pregnancy.

The uterus occasionally contains two or more embryos, resulting in twins, triplets, quadruplets, quintuplets, or sextuplets. Five reasonably authentic instances of sextuplet pregnancy are recorded. Many instances of a greater number of children at a single labor are reported in the older literature; they are purely legendary. The most remarkable of these legends is that of the Countess Hagenan, who was said to have been delivered of 365 embryos at a single labor. One hundred eighty-two of these embryos were reputed to be male, a like number female, and the remaining one a hermaphrodite. The basin in which these embryos were baptized is still shown as a relic. This legend is not without some foundation. The delivery was not of a prodigious number of embryos, but of a growth called a hydatidiform mole. These growths are rare abnormalities in which the processes which extend from the surface of the ovum into the wall of the uterus enlarge and appear like small grapes. The dilated endings might be mistaken for embryos. An analysis of 20,000,000 cases of labor showed that in 1.17 per cent more than one child was born. Twins occurred once in 89 labors, triplets once in 7,910, and quadruplets once in 371,125.

Most cases of multiple pregnancy arise from the fertilization of two ova. Usually only one ovum separates from the ovaries at the time of ovulation, but occasionally two, or even more, ova may be cast off simultaneously. If all of these ova are fertilized and implanted in the uterus, the corresponding number of embryos develop. These embryos are distinct; each has its individual membranes and placenta. The children born may be of the same or opposite sex; they resemble each other no more than do children born separately of the same parents. Some women appear to be predisposed toward multiple ovulation, and it is not unusual for them to have twins or triplets on several occasions. In some instances the tendency to multiple pregnancy follows the female line of a family through several generations.

Twins may occasionally follow from the fertilization of a single ovum. In such cases it is believed that the growing mass within the ovum separates at an early stage into two parts. These parts develop independently. Twins thus formed are inclosed in one sac and are joined to a single placenta. Such twins are identical; they are both of the same sex and resemble each other much more closely than children born separately of the same parents. Moreover, the primary cleavage of the cells in the ovum may occur in such a way that one of the twins formed is the mirror image of the other. In that event the normal position of the abdominal organs is reversed in one of the twins; the liver and appendix are upon the left side of the abdomen, and the heart inclines to the right instead of the left side of the chest. Where a similar inversion is found in a person who was not born with a twin, it is assumed that the twin formation occurred, but that the development of one of the pair was arrested at an early stage.

Monsters.

The formation of monsters bears a close relation to the development of twins from a single ovum. Identical twins represent the most complete primary cleavage; but all degrees of separation occur, and probably at various stages of development. As a result, monsters appear like the Siamese twins, in whom the separation was almost complete, or as two individuals united throughout the length of their bodies, or joined pelvis to pelvis. The cleavage may also affect only a portion of the embryo, producing double-headed or triple-legged monsters, or various parasitic monsters in which small legs, arms, or a trunk project from some point on the body. Finally the cleavage may involve only a small group of cells producing an excess of parts, such as extra fingers or two spleens.

Cleavage of the ovum does not explain all of the abnormalities in the growth of the fetus. A common malformation results from amputation of parts which have their circulation cut off by being entangled in the umbilical cord. The child is then born with a limb or hand undeveloped. Anomalous development may result in such defects as harelip or cleft palate, or they may

be so extensive that a monster is formed so misshapen that it cannot live.

Superfetation.

Twins formed from separate ova do not always develop at the same rate, for the supply of nutrition may be unequal. This inequality of size has given rise to the belief that the twins are of different age and arise from ova fertilized perhaps a month or two apart. Superfetation, as this suppositious process is called, is theoretically possible; but no well-authenticated instance of its occurrence has ever been recorded. On the other hand, it is possible for twins formed from separate ova to be fertilized by different males. The two ova are liberated simultaneously, and the separate impregnations occur within a short time of each other. Superfecundation, as this is called, is of common occurrence in animals such as the cat and dog.

Prenatal Influences.

The term prenatal influence or maternal impression has been the subject of much popular superstition; it means the imparting of some physical or mental attribute to the child as a result of mental impressions upon the mother during pregnancy. The antiquity of this belief is illustrated in the Biblical story of Jacob. As his share of the cattle he was to receive those which were ring-streaked and striped. To increase the number with these markings he exposed before the pregnant females branches upon the bark of which he cut the desired pattern. The number of ring-streaked and striped cattle born was supposed to be increased by this maternal impression.

The theory is fallacious; and yet in the last part of the last century a law was passed in a city of the United States which forbade crippled beggars from appearing on the street, for fear that crippled children would result from the impression made upon pregnant women. The Siamese twins were not allowed to exhibit themselves in Paris for a similar reason. Cases, interpreted as such maternal impressions, are firmly believed in by many people; but all of these examples lack one essential, they are uncontrolled. The child might have developed the same birth-

mark, malformation, or mental quirk without the exposure of its mother; the developmental abnormality may have occurred long before the mother received the impression. Furthermore, millions of mothers have been exposed to mental impressions and have nevertheless borne normal children; normal children are born to women in lands undergoing the devastation of war. Maternal impression is called in as an explanation to satisfy circumstances that occur by chance. It is a superstition, and nothing more. The mother has no more direct mental influence upon the development of the child than a hen has upon the egg it hatches.

Prenatal influence, aside from its superstitious aspect, has a real basis. The child during its stay in the uterus is a parasite upon the mother. Although there are no direct connections of nerves or blood vessels between the mother and the child, it nevertheless derives its nourishment from her. The relation is that of the growing tree to the soil. The nature of the soil influences the growth of the tree; if the soil is fertile, growth is full, but if the soil is barren, growth is stunted and perverted. The health of the mother influences the physical development of the child. If her health is impaired, the child suffers; likewise her mental state may react upon the child, but it can do so only indirectly by its influence upon the mother's health and thus upon the nourishment of the child. Such disturbances do not result in physical and mental abnormalities; they produce stunted children.

Lactation.

Both the male and female are provided with mammary glands, but they develop activity only in the female, for their activity is initiated by pregnancy. They secrete milk which provides the food for the newborn during its first year of life. The mammary glands are modified sweat glands. Each breast contains a group of twenty or more separate glands opening by independent ducts in the raised center, or nipple, of the breast. At the time of puberty the breasts of the female increase in size, but this enlargement is due to the growth of connective tissue and the deposition of fat. The glandular tissue remains rudimentary and functionless at this time. When pregnancy occurs, the mammary glands

are stimulated by an internal secretion, and as a result grow larger and contain a watery secretion known as colostrum. During the later months of pregnancy this secretion can be expressed from the breasts.

After the birth of the child the glands are further stimulated and a more abundant secretion is produced. For the first day or two this secretion retains the character of colostrum, but on the third or fourth day true milk is formed. Emptying the glands by milking prolongs their secretory activity. When the ducts of the glands are filled with milk, secretion is stopped, but it is reëstablished by emptying the glands. If the ducts are not emptied by milking, the secretion is suppressed within a few days and the glands become smaller. Their activity is reëstablished during the succeeding pregnancy. If conception occurs during the period of lactation, the milk is altered in composition and the flow is finally stopped.

It is believed that the internal secretion which initiates the activity of the mammary glands arises in the fetus, but this fact has never been established. That the control is exercised through an internal secretion is illustrated by the case of the Blazek sisters. These joined twins had a common circulation, but separate nervous systems. Pregnancy and birth in one was followed by a secretion in the mammary glands of the other. The same internal secretion acts also upon the mammary glands of the child before it is born, for during the first day or two after birth a milky fluid can be expressed from the breasts of children of both sexes. This secretion is popularly called "witch's milk."

Changes Accompanying Pregnancy.

The changes in the mammary glands and uterus are the two most distinctive effects of pregnancy; but in addition, the whole organism of the mother is affected both mentally and physically. The growing child is a parasite upon the mother; it supplies its wants with no consideration for the mother. The diet and the care of the pregnant woman can be, and should be, regulated to meet and counteract these debilitating influences. Even under the best care the mother is occasionally unable to withstand the drain upon her resources.

In the discussion of the urinary system mention was made of nephritis arising from pregnancy. It occurs when the kidneys are already weakened and are unable to carry the additional burden of excreting the waste material arising from the child. A diseased heart may likewise be unable to meet the strain put upon the circulation. Diseases such as tuberculosis and diabetes are adversely influenced by pregnancy. The dangers in all of these conditions can be detected by medical examination before pregnancy has occurred, and the risk incurred by pregnancy decreased by proper care. There are other diseases, however, arising as a result of pregnancy, which cannot be predicted. These conditions result from poisoning by some perversion of metabolism. Eclampsia and pernicious vomiting are the two most important. Eclampsia is a severe intoxication accompanied by convulsions; it occurs in the latter part of pregnancy. In the severe form of the disease the immediate removal of the child from the uterus is necessary in order to prevent the death of the mother. The early development of eclampsia can usually be detected by an examination of the urine and measurement of the arterial pressure. For this reason there should be frequent medical examinations throughout the entire course of pregnancy.

The digestion is often seriously disturbed by pregnancy, and vomiting occurs in about one-half of all pregnant women during the second and third months. This so-called "morning sickness" involves great discomfort, but usually ceases as the pregnancy progresses. In some cases, however, the vomiting becomes of such frequency and severity that no food can be retained. The condition is then known as pernicious vomiting, and it may be necessary to empty the uterus.

Duration of Pregnancy.

The duration of pregnancy is somewhat variable. In the majority of cases labor ensues approximately 280 days (10 lunar months) after the first day of the last menstrual period, so that the pregnancy is 275 days or less. This rule is subject to many exceptions; well-developed children may be born as early as 240 days and as late as 320 days after the last menstrual period.

Childbirth.

Parturition, or labor, consists in the expulsion of the child and its attachments from the uterus. The expulsive force is exerted by the muscles of the uterus and by those of the abdominal wall. The uterus is a muscular bulb and its only distensible opening leads through the cervix into the vagina. To effect parturition the uterus contracts intermittently upon its contents, forcing them against the cervix until the opening is dilated; it then expels them through the vagina. The cause of the onset of labor is unknown, although many theories have been advanced in explanation. Labor is an involuntary act and cannot be controlled by the will. It proceeds normally even when all the nerves from the central nervous system to the uterus have been cut.

The contractions of the uterus are nearly always accompanied by pain, the so-called "labor pains," but the amount of suffering varies greatly in different women. At the onset of labor the pains occur at intervals of from fifteen to thirty minutes; they gradually become more frequent and eventually occur every two or three minutes. Each pain lasts about one minute. The duration of labor is variable, and a much longer time is usually required for the delivery of the woman's first child than for subsequent children. Eighteen hours is an average figure for the duration of labor for the first child, and twelve for the second; but these figures are variable and labor may last from a few minutes to a day or even longer.

A large part of the duration of labor is taken up in the dilation of the cervix. The contraction of the uterus upon the membranous sac filled with fluid causes it to bulge forward and act as a wedge in forcing open the cervix. When the cervix is dilated to a size which will permit the passage of the child's head, the membranes usually rupture and their contents are discharged. The expulsion of the child through the vagina then commences. By the combined effort of the contraction of the uterus and of the abdominal walls—the latter acting much as in defecation—the child is pushed forward into and finally expelled from the vagina. Occasionally the membranes surrounding the child do not rupture during the delivery and the child is born in a sac popularly spoken of as a "caul."

The placenta remains attached to the uterus for a short time after the delivery of the child, and the umbilical cord extends from the newborn child back into the uterus. During the first few minutes after the child is born the vessels in the cord contract and force the blood which they contain into the child. The attendant then ties a piece of tape about the cord a short distance from the abdomen of the child, and severs the cord a short distance beyond the ligature. The ligature prevents the loss of blood from the child through the vessels in the cord. After a few days the stump of the cord separates and the remnant scars over, forming the navel. During the time it is healing the stump of the cord is an open wound and must be kept clean, otherwise it may become infected.

With the birth of the child the contractions of the uterus cease momentarily, but they are soon reëstablished and expel the placenta. When the placenta is detached from the wall of the uterus the eroded blood vessels are exposed. The hemorrhage from them is checked by the contraction of the uterus, which squeezes shut so firmly that the blood cannot escape.

The head of the newborn child is large in comparison with the rest of its body. Any passage through which the head can be forced will allow the remainder of the body to pass readily. Furthermore, the head is smooth and its sides curved so that it acts like a wedge in forcing the passage. In 96 per cent or more of all deliveries, the child is born with the crown of the head foremost. The child usually comes into the necessary head-down position in the uterus during the last month of pregnancy. Prior to that time, and after the fifth month when movement is first felt, the child is able to change its position within the uterus, and can readily be moved about by pressure from the outside. Toward the end of the pregnancy the rapidly enlarging head becomes heavier than the other parts of the body, so that it sinks downward and is held by the natural adaptation of the child in that position to the shape of the uterus. At the beginning of labor the head descends into the ring formed by the bones of the pelvis; it becomes engaged there, and the child then is in position to be expelled.

The plates of bone which form the skull of a child are not

firmly knit together at their edges as they are in the skull of an adult. During birth these bones are pressed into a shape conforming to the canal through which the head passes; in some instances considerable distortion of the head results. The natural shape is gradually resumed during the first week or two after birth. The bones do not cover the entire surface of the head; an opening, the "fontanell," covered by the scalp, can be felt in front of the crown and a smaller one behind the crown. The growth of the bones closes these openings before the end of the second year of life.

In 3 or 4 per cent of all deliveries the child is born with some part of the body other than the crown of the head foremost. The face, brow, or buttocks and legs may be the part presented first. Serious difficulty in delivery results when the face or brow is the part foremost because of the relatively large diameter of the head in these positions. So far as the mother is concerned, breech presentation causes no marked difficulty in the labor; but the danger to the child is greatly increased. The head is larger than the buttocks, and some time is required for it to emerge even after the buttocks have passed through. During this time the cord is compressed by the head against the side of the birth canal and the circulation to the child may be shut off. With good obstetrical practice most cases of breech, face, or brow presentation are delivered without serious damage to either the mother or child.

Contracted Pelvis.

A small pelvis forms an obstruction to the birth more often than does any abnormal position of the child. The pelvis is formed of a ring of bones through which the weight of the body is transmitted to the legs. The sides and front of the ring are formed by the innominate or hip bones. These bones when viewed from above are crescent-shaped. They meet in front and are joined by a strong ligament. In the rear they are joined by ligaments to the sides of the sacrum. The sacrum is part of the spinal column, but the vertebræ which form it are fused together so that it appears as one bone. The four or five vertebræ below the sacrum are small and form a tip, essentially a tail, known as

the coccyx. In the outer side of each innominate bone there is a socket which forms the joint for the bones of the thigh. The side of the innominate flares outward over this socket and forms the hip. The pelvis of the female is adapted to the function of childbearing. It is shorter, less conical, and more lightly built than the pelvis of the male. Furthermore, the internal diameter measured from the front to the back is greater in the female.

During birth the child must pass through the ring formed by the pelvic bones. If the size of the opening is insufficient to

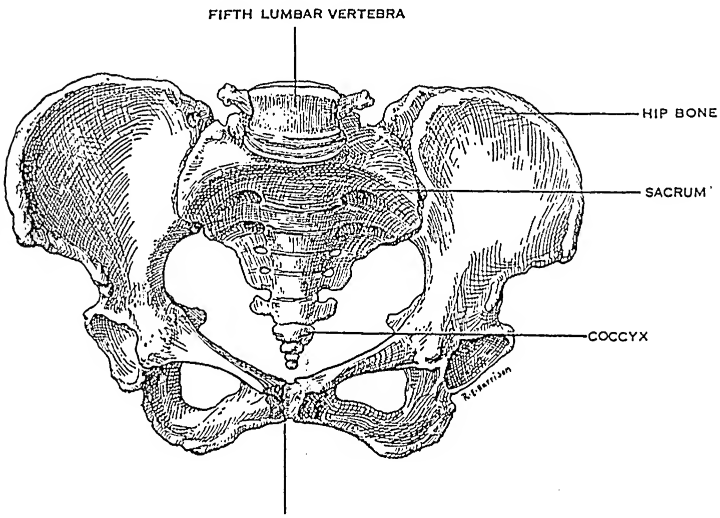


Figure 72. Bones of the Pelvis, Female.
The pelvic ring.

permit the passage of the head of the child, or to permit it with difficulty, birth in the normal manner is impossible or difficult. Fortunately, the physician is able to make measurements of the opening beforehand; he can thus detect abnormalities before labor has commenced. These measurements form a part of all proper medical care for the pregnant woman; they should be made early in the pregnancy.

A common deformity of the pelvis results from rickets. This disease is much more frequent among negroes in America than among white women. Lack of proper development of the bones of the pelvis, or their overdevelopment, deformity of the spine, and other abnormalities also result in a small or deformed pelvis.

When it is impossible for the child to pass through the opening of the pelvis, the surgical operation of Cesarian section may be employed to make the delivery. In performing the operation of Cesarian section the abdomen is opened and the child is removed through a cut made in the wall of the uterus. When the abnormality of the pelvis is determined by measurements and the operation is performed before labor has started, the effects upon the mother are no more serious than those from other abdominal operations. Moreover, the child is not injured. Cesarian section does not prevent the birth of subsequent children through the same procedure. Delivery by Cesarian section cannot be accomplished when the head of the child has been forced into the pelvic ring by the contraction of the uterus. If the further passage is blocked by the small size of the pelvis, little can be done except to crush the head of the child with a steel instrument and remove it. The preliminary measurements and careful medical observation of the pregnant woman have as one of their objects the avoidance of this drastic procedure.

The delivery of a child by means of forceps does not take the place of the operation of Cesarian section. Forceps are instruments designed to seize the head of the child and allow the physician to assist in delivery by pulling upon the head. The use of forceps is limited to deliveries in which the pelvis is of normal size. They are useful when the muscle of the uterus is weak and cannot exert the necessary expulsive force. They are likewise used to hasten the delivery when any condition endangering the life of the mother or child arises during the delivery. Obstetrical forceps intended to deliver living children were invented in the sixteenth century. Their use was kept a secret in one family of physicians and they did not come into general employment until the eighteenth century. Prior to their invention the only way of assisting labor was to insert a hand into the uterus, turn the child, and exert traction upon the feet. Infection, septicemia and death in the mother often resulted.

Premature Birth.

The terms abortion, miscarriage, and premature birth are synonymous to the extent that they signify the expulsion of the

contents of the uterus prior to the normal time of labor. The term abortion is used properly when the expulsion occurs before the third or fourth month of pregnancy; miscarriage between this time and the seventh month, and premature birth after the seventh month. The term abortion is commonly used by the medical profession to cover both the terms abortion and miscarriage; the laity, on the other hand, use the term miscarriage because the term abortion has in its common use come to mean the criminal procedure.

It is estimated that one out of every five or six pregnancies terminates prematurely. The most common causes are inflammation or displacement of the uterus and abnormalities in the development of the fetus. After the fourth month systemic disease of the mother becomes the commonest cause. The induction of abortion by artificial means is a criminal act, except when the physician deems the procedure necessary to preserve the life or health of the mother. In this case the contents of the uterus are completely removed by surgical operation. Criminal abortion is unfortunately common; its detection is difficult. The illegality of the procedure makes it especially dangerous to the health of the woman, for the risk of punishment forces the practice into the hands of those who are ignorant of the principles of surgical cleanliness. Killing the fetus with a sharp instrument, as they commonly practice it, sometimes leads to fatal perforation of the uterus and often to the introduction of infection. Moreover, portions of the membranes and attachments may be retained in the uterus and cause prolonged hemorrhage and inflammation.

Puerperal Infection.

The interior of the uterus is left raw and bleeding by the birth of the child. Normally this surface is free from bacteria and heals without infection. If bacteria of a dangerous type are introduced during the manipulations of the delivery, severe and often fatal infection results. Childbirth fever or, as the condition is more correctly called, puerperal infection, has probably occurred as long as children have been born. Many theories were advanced as to its cause, the most popular being that it resulted

from a retention of material in the uterus. It was only in the middle of the last century that its infectious nature was recognized. In America, Dr. Oliver Wendell Holmes was the great exponent of the contagious nature of the disease. He maintained that it could be traced to lack of proper precautions on the part of the physician and nurse. Holmes's view was scoffed at by prominent physicians of his time. It was not until the influence of Lister's teachings and the development of bacteriology brought about a revolution in the treatment of wounds, that the infectious nature of the disease was fully established.

Formerly puerperal infection killed many women. At times it occurred in epidemics; and in some maternity hospitals the mortality rose to such a height that the population revolted against these institutions as menaces to public health. The mortality records in Chicago showed that for the forty years prior to 1896, puerperal infection was assigned as the cause of death of 13 per cent of the women dying between the ages of twenty and fifty years. During this same period similar, or even worse, conditions prevailed in every city in the world.

With recognition that the procedures at delivery must be carried out with the same precautions as in a surgical operation, the mortality from puerperal infection has greatly diminished and particularly in hospitals. The doctrine of asepsis, however, has not even to this day permeated fully to the midwives who take charge of a large proportion of all obstetrical cases. Puerperal infection still occurs, but with diminishing frequency and no longer in epidemics.

A great variety of bacteria may cause puerperal infection, just as they may cause the infection of other wounded surfaces. Some bacteria, particularly the streptococcus, cause a more virulent type of puerperal infection than do others. Regardless of the type of organism causing the disease, its occurrence depends in nearly every case upon direct infection of the uterus through lack of cleanliness on the part of those assisting at the delivery. Cleanliness is the supreme virtue of the modern hospital and of competent physicians. Even the poorest people can obtain such service, for in all large cities maternity hospitals are operated at a low

rate and many have an out-patient obstetrical service which is free. The well-to-do patient can obtain the necessary cleanliness in delivery by making the same careful choice of a physician for obstetrical procedures as she would for a major surgical operation.

CHAPTER XXIII

GROWTH AND DEVELOPMENT, ALSO DISEASES OF CHILDHOOD

The Newborn Child.

Usually a child cries as soon as it is born, and in crying respiration is established. During the life of the child in the uterus the blood from the right side of the heart does not pass through the lungs, but is short-circuited directly to the left side of the heart through an opening in the septum between the auricles. With the first breath this opening is closed and the pulmonary circulation is established. Occasionally a child does not spontaneously start breathing when it is born; it is then necessary to employ measures essentially like those of resuscitation in order to start respiration. To this end the child's skin is irritated either by friction or by cold water, and in extreme cases artificial respiration is used, sometimes combined with the inhalation of oxygen containing 5 per cent of carbon dioxide (see Chapter X). When normal breathing is established the child is wrapped in a blanket. A drop of silver nitrate solution is put in each eye; this is a very important prophylaxis against purulent conjunctivitis leading to blindness. The baby's body is then thoroughly oiled to remove the sebaceous secretion which covers it, and it is washed in warm water. The stump of the cord is covered with a sterile dressing, and the abdomen is wrapped in a flannel band eight to ten inches wide, pinned snugly. The band is worn during the first few months. The child is dressed, placed in its crib, and covered with blankets. The crib is placed in a darkened room. Young infants should not occupy the same bed as the mother because of the danger of overlying, the mother in her sleep rolling over upon the child and smothering it. Some crying is natural; it exercises the lungs and keeps them properly expanded, but it should not be overlooked that crying arises from discomfort, and that it stops when the child is again comfortable. In a maternity

hospital where women of the working class are delivered, the infant's crib should stand by the mother's bed, as the opportunity to look at her child keeps her much more contented than if the child is kept between nursings in another room out of her sight.

Although the regulation of body temperature is imperfect at first, the clothing of the infant should be light and loose, as well as warm. It should be supported from the shoulders and not from a waistband. Elastic bands, such as garters, should not be placed on the limbs; for the soft flesh allows the elastic to sink in and impede the flow of blood. It is a common mistake to overload children, especially infants, with bed covering at night.

Development of the Nervous System.

Normal, healthy development of the nervous system depends upon quiet, rest, and freedom from excitement. The brain grows more during the first two years than during all the rest of life. It is very important for proper nervous development that infants should not be played with. Stimulating them to laughter and excitement by sights, sounds, or movements until they shriek with apparent delight is injurious to the still delicate and developing nervous system of the child. It is especially harmful when done just before the child is put to rest for the night. A child is not a plaything, as many adults seem to think.

During the first two or three days the normal infant sleeps almost continuously; during the first few weeks it sleeps from twenty to twenty-two hours out of the twenty-four, waking only from hunger and discomfort due to urine and feces. During the next six months the healthy infant sleeps sixteen to eighteen hours in the twenty-four; during the second year fourteen to fifteen hours. Disturbed or irregular sleep in infants is mainly due to two causes—hunger and indigestion.

Muscular Development.

Observations on growth—that is, increase of weight—are of the utmost importance during infancy and childhood. By this means diseases are detected in their incipiency. The child should be weighed each week for the first six months, bimonthly for the rest of the year, and monthly during the second year. The nor-

mal and healthy infant shows a gain at each weighing. Normally a gain of approximately fourteen pounds is made during the first year and six pounds during the second.

The first voluntary muscular movements are made about the third or fourth month; the infant then attempts to grasp objects placed before it. At about this time also the head can be held erect when the body is supported. The child can sit up at the seventh or eighth month. In the ninth or tenth month it makes the first attempts to pull itself up so as to bear its weight upon the feet. The first attempts at walking are commonly made in the twelfth or thirteenth month. The average age at which children walk alone is the fourteenth or fifteenth month. There is a considerable variation in the age at which children walk; sometimes marked differences are seen in different families. Rickets is the most common cause for considerable delay in walking. A child should not be restrained from standing or walking when inclined to do so. The belief that children are made bow-legged by premature standing is fallacious; children in whom the legs are markedly bowed usually have rickets, and the deformity develops regardless of standing. On the other hand, a child should not be urged to stand or walk, but such matters should be left to its own voluntary action. Flat foot may develop from premature standing.

The eyes of the newborn are very sensitive. The infant should be placed in a darkened room and protected against strong light for the first six weeks. The muscles of the eyes of the newborn do not coördinate until about the end of the third month. They cross their eyes frequently, but if this habit persists it may lead to squint. It may be prevented, in some cases at least, by placing the playthings, food, etc., for the child so that they must be reached for at arm's length instead of being held close to the face. For the first twenty-four hours after birth infants are deaf; the deafness sometimes persists for several days. It is believed that this is due to absence of air in the middle ear.

Speech.

There is a wide variation in the time at which speech develops. Girls as a rule talk from two to four months earlier than boys.

Toward the end of the first year the average child begins with one or two words. By the end of the second year he is able to form sentences of two or three words. Progress from that time on is rapid. Names of persons are commonly acquired first, then names of objects, after which come verbs and finally adverbs and adjectives. If a child of two years makes no attempt to speak it may usually be inferred that it is mentally defective or that it is deaf.

Dentition.

The time at which the first teeth appear and also the order in which they appear is subject to considerable variation.

TABLE X

ERUPTION OF TEMPORARY TEETH

Two lower central incisors	6 to 9	months
Four upper incisors	8 to 12	"
Two lower lateral incisors and 4 anterior molars	12 to 15	"
Four canines	18 to 24	"
Four posterior molars	24 to 30	"

At 1	year a child	should	have	6	teeth
At 1½	years a "	"	"	12	"
At 2	" " "	"	"	16	"
At 2½	" " "	"	"	20	"

In rare cases an infant may be born with one or more teeth; usually the lower central incisors. Long-delayed dentition is usually due to rickets. Even in healthy infants the first teeth may not appear until as late as the tenth month. During teething the child often becomes restless and irritable; the saliva flows excessively and the appetite is diminished. Formerly it was believed that the eruption of the deciduous teeth was associated with systemic disturbances, and most illnesses occurring between the ages of six months and two years were attributed to this cause. Coincident disease of the ears, lungs, stomach, and intestines were often overlooked because of the belief that the child was "only teething."

The temporary teeth need the same care and regular inspection by a dentist as do the permanent teeth. When decay starts in the temporary teeth its progress is rapid. The resultant abscesses in

the jawbone infect the permanent teeth which are developing below them, and the absorption of the infectious material disturbs the normal growth of the child in other respects also. Premature loss of the temporary teeth interferes with the growth of the jaws and the spacing of the permanent teeth, so that crowding and irregularity result (see Chapter II).

The first permanent teeth to appear are the six-year molars which come in behind the molars of the first set, room being made for them by the growth of the jaw. The permanent incisors and canines replace the corresponding temporary teeth, and the eight bicuspids take the place of the eight temporary molars. As the permanent teeth grow outward the roots of the temporary teeth are absorbed, so that these teeth loosen and fall out.

TABLE XI

ERUPTION OF PERMANENT TEETH

First molars	6 years
Incisors	7 to 8 "
Bicuspids	9 to 10 "
Canines	12 to 14 "
Second molars	12 to 15 "
Third molars (wisdom teeth)	17 to 25 "

Infant Mortality.

Nearly a quarter of all deaths occur during the first year of life. In backward countries more than half the children born die during the first year; in fact, infant mortality is one of the best measures of the grade of civilization. The first weeks of life are the period of highest mortality, for during this time the strain of adaptation to the new environment is most severe. After this period each month shows a declining death rate. The mortality for infants in the second year is only about 6 per cent of the deaths at all ages. The following table gives comparative figures for deaths in New York City during the years 1907 to 1909 inclusive:

COMPARATIVE AGES AT DEATH, NEW YORK CITY, 1907–1909

Under 1 year, 30,626, or 22.5	percent
1 to 15 years, 19,779, or 14.5	"
Over 15 years, 85,741, or 63	"

In large cities of the United States in 1900, from 135 to 260

infants out of each 1,000 born died during the first year of life. The death rate was highest in the cities whose populations are engaged in manufacture, such as Fall River and Lowell, Mass. The death rate is highest in the congested parts of cities. The congestion itself is probably a relatively unimportant factor in the baby's life, but the conditions which usually, although not

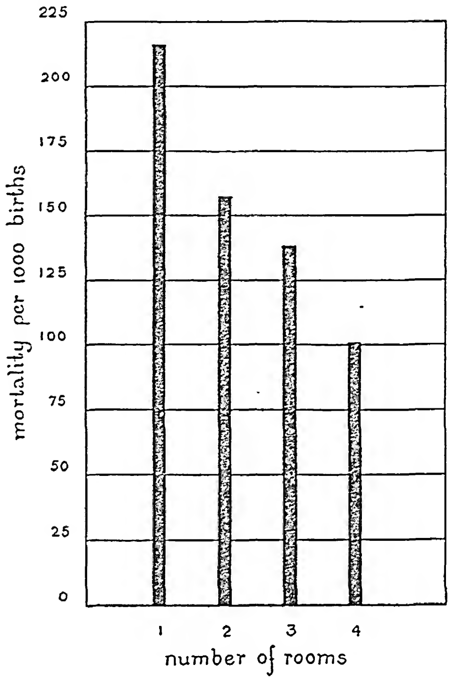


Figure 73. Infant Mortality in Relation to the Number of Rooms Occupied by the Family. (One borough of London, 1905.)
The congestion itself is not the direct cause of the high mortality; the important factor is the unsanitary conditions which often accompany the congestion.

necessarily, are the accompaniment of congestion—dirt, insufficient light and air, carelessness, and ignorance—are extremely important. Figure 73 shows the infant mortality per 1,000 births in one borough of London in 1905, in relation to the number of rooms occupied by their families.

Intemperance, employment of the mother in certain injurious occupations, notably industries dealing with lead, or in any occupation which deprives the infant of constant care during the early months of its life, directly increase the infant mortality.

The predominating influence of cleanliness and care is summed up in an estimate which has been made in England; in wealthy families 10 per cent of the babies die in their first year, in the middle class 21 per cent, and in the laboring class 32 per cent.

Infant Feeding.

Gastro-intestinal disorders and disturbances of nutrition account for half the deaths during the first year of life; both are dependent upon the feeding of the infant. The change in nutrition at birth is abrupt. Before birth the child derives its nourishment by diffusion from the blood of the mother; that fluid contains every essential nutriment in the most available form. After birth the child obtains its food only through its digestive tract; that system is as immature as is the infant as a whole.

The mother's milk is the ideal infant food. Babies fed from the breast usually thrive; and they are much less liable to disease of the gastro-intestinal tract than are babies fed on artificially prepared foods. Fully four-fifths of the deaths under one year are in infants who are fed on artificially prepared foods.

The composition of the mother's milk is affected by her physical and mental state; if she is ill it may become unsuitable for the child. Proper diet, regular habits of sleep and exercise, and freedom from excitement, worry, and overwork are essential for the successful nursing of the child. The capacity for nursing appears to be steadily diminishing in America. Few mothers in the well-to-do classes are able to continue satisfactorily beyond the sixth month. A similar decline, although to a less degree, is seen in the poorer classes. The decrease is more serious among the latter, for they lack the facilities, and in many cases the intelligence, for proper artificial feeding.

In Europe the so-called "wet nurse" is often employed instead of artificial feeding. When maternal nursing becomes impossible another woman nurses the child. The danger of transmitting contagious diseases is the only serious objection to this procedure. In America there are practical obstacles which generally preclude wet nursing; wet nurses are recruited from the peasant class and in this country that class does not exist.

Artificial Feeding.

Any substitute for mother's milk should furnish the same constituents and in the same proportions as they exist in human milk. No food except fresh milk, usually cow's milk, meets the requirements even approximately. Although cow's milk furnishes the required constituents, they are not in the proportions suited to the human young, nor are the constituents of exactly the same nature as woman's milk. Usually, cow's milk must be modified before it can be used. Cow's milk contains approximately twice as much protein, and only a little more than half as much carbohydrate as human milk. The earliest milk modification was simply dilution with water to reduce the concentration of protein, and the addition of enough cane sugar to bring the carbohydrate to the proper concentration. A similar modification, usually with the substitution of milk sugar or other carbohydrate for the cane sugar, is largely used today.

Although there is no satisfactory substitute for milk, nevertheless a variety of preparations are manufactured and sold as substitutes. Although these compounds are condemned by authorities on infant feeding, they are widely advertised and extensively sold. When given without the addition of milk, rickets and scurvy follow their prolonged use. These foods are composed largely of carbohydrates, and are lacking in fat and often in suitable protein; some even contain a large per cent of raw starch. The rich carbohydrate diet supplied by these foods often makes a child large and apparently fat. Actually the child is not fat, but contains an excess of water; this water is quickly lost and the weight correspondingly decreased, even by slight illness. The picture of the child gives an impressive appearance in advertisements; but such children are usually soft, flabby, and offer little resistance to disease.

Bacteria in Milk.

Human milk taken directly from the breast is practically free from bacteria; the only contamination is by a relatively few cocci from the skin about the nipple. Cow's milk, when delivered to the consumer, usually contains a large number of bacteria. Certain of the organisms which may be present, notably

tubercle bacilli, arise from the cows themselves; others are introduced during the handling of the milk. Among the latter may be the organisms of such infectious diseases as scarlet fever, diphtheria, and typhoid. More often there are bacteria which do not cause specific human disease, and arise from the dirt and dust about the stable; these bacteria when present in large numbers are believed to play a part in causing the diarrhea of infancy.

Most bacteria grow readily in milk, but keeping the milk cold inhibits the growth. The number of bacteria in any sample of milk depends upon the original contamination, the temperature at which it has been kept, and its age. The three influencing factors are illustrated by the following observation: A sample of milk was taken in a clean dairy containing at the time only 300 bacteria in each drop. It was cooled to 45° F. and kept at this temperature. After 24 hours each drop contained 400 bacteria; after 48 hours 900, and after 72 hours 150,000. Another sample taken in an uncleanly dairy contained at first 2,000 bacteria per drop and in 72 hours 16,500,000. In another test 4 samples of the same milk were kept at different temperatures for 24 hours; the bacteria in equal quantities of each were then estimated.

Sample	1,	kept	for	24	hours	at 60° F.	contained	134,340	bacteria
"	2,	"	"	"	"	" 55° F.	"	67,170	"
"	3,	"	"	"	"	" 50° F.	"	1,362	"
"	4,	"	"	"	"	" 45° F.	"	448	"

Pasteurization of milk (see Chapter IX) kills the organisms causing the specific infectious diseases, but does not kill all of the other bacteria in the milk. After pasteurization the milk must be kept cold to prevent their growth. Milk may be sterilized by heating it to the boiling point for five minutes. This boiling alters the composition of the milk to some extent and lowers its vitamin content. The use of such milk as the sole diet for a long time may lead to scurvy and other forms of malnutrition. Great improvement has been made in recent years in the handling and distribution of milk. In most cities the regulations governing these matters are rigidly enforced. In addition, numerous health centers distribute milk properly modified for each infant at a low cost and in some cases free. These centers

also make frequent examinations of the infants to whom the milk is distributed, and instruct the mother in the proper care of her baby. Such institutions contribute largely to the progressive decline in infant mortality which has taken place in recent years. Day nurseries for the care of infants of women who work in factories have also aided considerably in this reduction.

Fruit juice is an important addition to the diet during the first year. Orange juice or the juice of canned tomatoes is given daily after the third month, and the amount is increased from a teaspoonful to one or two ounces by the end of the year. Iron is added to the diet usually in the form of beef juice beginning with the second year. During this year the diet is gradually altered to include eggs, gruel, cereal, and broth. Milk is continued, usually as unmodified but pasteurized cow's milk.

Periods of Growth and Development.

Several different periods are recognized in the growth and development of the body. The boundaries between the periods are not sharply defined, but are determined by the characteristics which prevail after they have become established. The main periods are:

(1) Infancy: the first and second year of life.

(2) Childhood: the period extending from infancy to the appearance of the first permanent teeth, or about the seventh year.

(3) Boyhood or girlhood: the period extending from childhood to puberty, which usually comes at the thirteenth or fourteenth year.

(4) Adolescence: the period beginning at puberty and terminating at maturity, which is about the sixteenth or seventeenth year for women, and the twenty-first year for men.

These four periods complete the growth of the body.

(5) Maturity: the period extending up to the prime of life, forty-fifth to fiftieth year, or the climacteric in women. During this period men and women exercise their full physical and mental powers.

(6) Old age: the period beginning in the late forties or early fifties and characterized by various chronic disorders gradually encroaching upon the normal functions. The physical and mental

powers are upon the wane but they do not necessarily follow parallel courses.

(7) Senility: the degeneration of the powers of mind and body which may occur in the sixties, but often not until the eighties or even nineties.

Rate of Growth.

Growth measured as a percentage increase in height or weight is very rapid during the early years of life, but the greatest gross increase occurs during the period of adolescence. The average weight of a child at birth is seven to seven and one-half pounds, with reasonable extremes of five to eleven pounds. During the first two or three days after birth the infant loses weight, then commences to gain, and by the seventh to fourteenth day regains its birth weight. In the first six months the weight is doubled, and by the end of a year tripled. At birth the average child measures twenty to twenty-two inches in length, and by the end of the third year has reached about half the stature it will attain at full growth.

The growing period of the female is shorter than the male; maturity and cessation of growth come at an earlier age and with less stature and weight. After the tenth or twelfth year the female grows more rapidly than the male of equal age, and is both taller and heavier until the sixteenth or seventeenth year, when the two sexes are again of equal weight and height. After the seventeenth year women grow comparatively little, while the growth of the male continues up to the twentieth or twenty-first year.

During growth the percentage increase in weight is greater than the increase in stature. This means that the body fills out as well as elongates, but less than as the cube of the height. The weight per unit of length becomes greater as maturity is approached. Thus the weight of an average boy or girl of seven, 20 kilograms, divided by the height, 11.5 decimeters, gives a value of 1.8; at fourteen years this becomes 3.0, and at maturity the average figure is 4.0. For a young adult a height-weight relation in decimeters and kilograms of 4.0 represents good proportioning of the body, 5.4 obesity, and 3.6 emaciation. These same

values given in the relation of inches and pounds are 2.2, 3.0, and 1.9, respectively.

Factors Concerned in Growth.

Three factors are concerned in growth: (1) the inherent hereditary properties of the organism; (2) the nutritional factor, an ample supply of suitable food materials; and (3) the health factor, freedom from diseases which arrest the growth. The hereditary factor establishes for an individual the possible rate of growth and the point at which it ceases; nutrition and health are modifying influences which may retard growth but never make it exceed its normal rate. Even with proper nutrition and good health individuals grow at different rates and attain different statures. The growth factor is to some extent influenced by immediate heredity; large parents tend to have large offspring, and small parents small offspring. There is a different average height for the people of different races. Little is known concerning the fundamentals of the growth factor; it is very sensitive to a deficiency of vitamin A in the diet and to the activity of certain of the internal secretions of the body.

Regardless of the differences in rate of growth, the course of growth for each period follows a similar course or curve. When the growth is temporarily arrested, the deficit is not made up; maturity is then attained with a stature less than the normal. Thus the cretin who is stunted by a lack of secretion of the thyroid gland commences to grow when thyroid medication is given, and the rate of growth is approximately that which would take place in an equal time in a normal child of the same age. If the thyroid extract is commenced in early childhood the stature reached at maturity may be nearly normal; but if the medication is delayed until maturity has been reached no growth follows. Similarly, when the growth is stunted by lack of food, insufficiency of vitamin A, or by disease, such as hookworm infection, the deficit caused by the condition is permanent. Although normal growth is resumed when a healthy state is restored, it continues only at a rate normal for the age.

Although lack of thyroid secretion retards growth, an excess does not accelerate the normal rate. The pituitary gland, which

is another gland of internal secretion, has a more positive influence upon growth, particularly of the skeleton. This gland, which is about the size of a pea, is connected by a stalk to the underside of the fore part of the brain. It rests in a depression of the bones of the skull which form the bridge back of the nasal cavity. Although the gland is very small, it consists of two parts, each with a separate function; the rear portion produces a secretion which exerts an influence over the state of contraction of the involuntary muscles, while the fore part is concerned with the regulation of growth and development. (See Figure 40.)

Occasionally the pituitary gland is stimulated to excessive activity; as a result growth becomes abnormal. If the condition occurs in a young person before the bones of the legs and arms have completed their normal development, a remarkable elongation results, the condition called gigantism. A stature of seven feet or more may be attained. If the disease starts after maturity when the bones have become firmly knit, the effects of the hypersecretion are most marked in the face. The lower jaw is enlarged, as are also the bony ridges over the eyes. The hands are increased in size, so also are the vertebræ which make up the spine, but the stature does not increase, for the back is curved forward. The disease which is caused in adults by hypersecretion of the pituitary is not called gigantism, but acromegaly.

Very rarely a deficient or hyposecretion of the pituitary gland may occur and cause an arrest of development which is usually associated with other abnormalities of the body. In exceptional instances true dwarfing is produced; the individual, although only three or four feet in height, is the miniature of a man or woman with all the lineaments of the adult.

Puberty denotes the period of development during which sexual function reaches maturity and the so-called secondary sexual characters make their appearance. Up to the time of puberty the configuration of the bodies of the boy and girl is quite similar. Through the development of the secondary sexual characters, the female form is rounded out by a deposit of fat under the skin, the breasts develop, and menstruation starts; correspondingly, the male commences to show a beard, the larynx is broadened, and the pitch of the voice is lowered. It is prob-

able that certain glands of internal secretion play a rôle in the development of puberty, particularly the outer portion of the adrenal glands. The adrenal glands, as the name implies, are situated just above the kidneys. They are triangular in shape and each weighs about an ounce. Enlargement of the outer portion of the glands is accompanied by sexual precosity; a boy, for instance, of four or five years may possess the sexual development of a mature male, hair grows upon the chest, and a mustache or beard may develop, while in a girl the breasts develop and menstruation may start.

Rickets.

Numerous derangements of health and growth arise from faulty nutrition. The four outstanding conditions of this type are malnutrition, marasmus, scurvy, and rickets. Malnutrition, as the name implies, is a condition in which the child, without having any particular organic disease, fails to thrive under the ordinary methods of feeding. The condition often has its cause in a constitutional enfeeblement of the child, inherited, due to premature birth, or induced by neglect. Marasmus is a severe form of malnutrition; the child loses weight to the point of extreme emaciation. Scurvy, in contrast to malnutrition, is a disorder of the diet alone. Its causation from deficiency of vitamin C is discussed under the section devoted to the vitamins (Chapter V).

Rickets is a disease which occurs especially between the ages of six and eighteen months. The main manifestation of the disease is in the bones. The deposition of calcium does not progress normally; in consequence the growing bones are soft and distorted. A well-developed case of rickets presents an unmistakable picture. The head is large and is flat on top. The ribs are roughened and feel like beads to the touch, the "rachitic rosary." The chest is narrow and the abdomen protruding. The wrists and ankles are swollen. The legs, and to a less extent the arms, are bowed. In older children pronounced bow-leggedness is the outstanding feature of the disease. The disturbance caused by the disease is not limited to the bones; the growth of the whole body is disordered. The muscles are soft and flabby. The eruption of

the teeth is delayed. The child is particularly susceptible to infections.

Rickets is due to lack of sunshine; specifically, to the lack of sufficient actinic light rays acting upon the skin. The disease is rare in rural districts and in the countries where the climate permits the children to be out-of-doors in all seasons. It is common in the congested sections of cities in the temperate zone, particularly among the Italian and Negro inhabitants of these districts. Negroes, and to a less extent Italians, have dark skins which protect them against the penetration of actinic light, which is relatively strong in the countries to which they are native. Actinic light in too great intensity is irritating to the skin, causing sunburn. The relatively feeble actinic light in the temperate zone, particularly in smoky cities, is insufficient for the dark-skinned people, unless the exposure is unusually prolonged. The exposure, moreover, must be to the out-of-door sunlight, for glass bars the passage of most of the actinic light rays. New forms of glass are now being introduced which allow the actinic light to pass. Certain food substances, notably cod-liver oil, can to some extent replace exposure to sunlight in preventing and curing rickets.

Rickets is a chronic disease; its changes are progressive and slow. Likewise the recovery which follows the administration of cod-liver oil and exposure to sunlight is slow. The bones gradually resume normal growth, minor deformities disappear, and the greater ones are much improved. In severe cases some bowing of the legs persists and in girls the pelvis is often permanently deformed, rendering normal childbirth difficult or impossible.

Measles.

As a cause of death measles ranks first among the acute fevers of childhood. The mortality from the disease itself is low except in infants and delicate children, but broncho-pneumonia occurs as a common sequel. The mortality from this complication is high.

Measles is a widely prevalent disease. Nearly everyone is susceptible unless protected by a previous attack. While pri-

marily a disease of childhood, it also attacks adults of all ages. When introduced into the Fiji Islands in 1875, 40,000 inhabitants out of the total of 150,000 died from measles within four months.

Measles has a period of incubation of from eleven to fourteen days. The first symptoms are those of a head cold, with some fever. The distinguishing eruption of the disease does not develop until the third or fourth day of this stage, when small red spots similar to flea bites appear upon the skin of the face and spread slowly over the body. The period of eruption lasts from four to six days. After the rash fades the skin peels off in small scales. Measles is spread by contact. The secretions from the nose and mouth carry the contagion. It is present in these secretions even during the first stage and hence before the typical eruption has appeared. This fact makes it difficult to guard against the transmission of the disease, since the symptoms at this stage are merely those of a common cold.

Although it is a common disease, measles is not to be regarded lightly; even during the period of convalescence constant watchfulness and care are necessary to prevent the development of pulmonary complications. Many cases of broncho-pneumonia and tuberculosis arise from "catching cold after measles."

German measles is a disease distinct from measles; it attacks those who have had measles as well as those who have not. It resembles measles, but it is much milder, is never fatal, and is rarely followed by any complications.

Chicken-pox.

Chicken-pox is a contagious disease which is rarely fatal. The period of incubation is ten to fifteen days. Fever then develops and within twenty-four hours the typical eruption appears. Small red spots rise above the surface of the skin. Within a few hours these spots are transformed into vesicles containing a clear fluid. A day or two later pus replaces the fluid. The pustules gradually shrivel and are converted into scabs which fall off and as a rule leave no scar unless they have been scratched.

Smallpox is sometimes mistaken for chicken-pox, particularly when the case is mild. The correct diagnosis may not be made until a fatal case occurs.

Smallpox.

Smallpox is not distinctively a disease of childhood, for it is common at all ages. It is, however, particularly fatal to children. Of the 3,164 deaths in the Montreal epidemic of 1885-6, 2,717 were of children under ten years of age. It is included in the list of contagious diseases given here because of the importance of applying its preventive, vaccination in childhood.

Smallpox is an ancient disease; it existed in China many centuries before the Christian era. At the time of the Crusades it spread throughout Europe. In this day of general vaccination it is difficult to realize that smallpox was one of the scourges of mankind; it depopulated cities and almost exterminated nations. During the eighteenth century approximately 60,000,000 people died of the disease in Europe.

Smallpox was introduced into the Western Hemisphere by the Spaniards fifteen years after the discovery of America. Within a short period thereafter three and one-half million persons in Mexico are said to have died of the disease. Half of the American Indians died of smallpox. In Iceland in 1707, 18,000 perished out of a population of 50,000. The epidemic of 1752 in Boston furnishes a good example of the wide ravages of the disease. At that date the population of Boston was 15,684. Of this number 5,998 had previously had smallpox. During the epidemic 5,545 persons contracted the disease in the usual manner, 2,124 took it by inoculation, and 1,843 fled from the city to avoid infection. There were, therefore, left in the city only 174 who had not had smallpox.

Smallpox is one of the most virulent of the contagious diseases; persons exposed to it, unless they have had the disease or are protected by vaccination, are almost invariably attacked. The death rate may rise as high as 35 per cent. The period of incubation is about twelve days. The disease is then usually ushered in by intense headache, severe pain in the back, and vomiting. There is high fever. The characteristic eruption appears usually on the fourth day. The spots are raised above the surface. At first they are red, but subsequently they change into pustules. With the first appearance of the eruption the fever falls and the general symptoms subside, but both return

when pus forms in the vesicles. During the third or fourth week of the disease the pustules break and exude their pus, or they dry and form scabs. In severe cases deeply pitted scars are left after the vesicles have healed. Milder cases may clear up without leaving scars.

The disease appears in several types. In the mildest form the pustules are some distance apart and each is distinct. In a more severe form the pustules run together, so that a sheet of pus spreads beneath the surface of the skin of the face and extremities. In still another type there is hemorrhage into the skin, giving rise to the name "black smallpox."

Prophylaxis by Inoculation.

Prior to the introduction of vaccination the only prophylaxis against smallpox was inoculation with the virus of the disease. Material was taken from the vesicle or pustule of a mild case of smallpox and introduced into the skin by means of a small cut. The disease which develops is a form of true smallpox, and although it is usually mild, it is nevertheless contagious. The disease transmitted from an inoculated person to another is not necessarily mild, but may be of a serious or even, in rare cases, fatal form. Inoculation with smallpox protects the individual with reasonable safety, but it endangers the community. Inoculation is a very old custom practiced by the Chinese from time immemorial. It was introduced into Western civilization by Lady Mary Montagu, who learned of the method in Constantinople, and had her own boy "engrafted" with successful results. The practice soon became popular in England (1721) and was introduced into America by Dr. Bolyston of Boston. Washington had his entire army inoculated. The introduction of vaccination with cowpox has completely replaced the practice of inoculation.

Prophylaxis by Vaccination.

Cowpox is an eruptive disease of cattle which is transmitted as a mild disease to persons handling the animals. For centuries it was a popular belief among farmers that cowpox protected against smallpox. Dr. Jenner of England became convinced

of the truth of this belief, tried it experimentally, and in 1798 introduced vaccination. He proved its effectiveness by vaccinating a boy, and then inoculating him with smallpox. No smallpox resulted.

Vaccination was introduced into the United States in 1800. In Boston in 1802 a crucial demonstration was made of its efficiency. Nineteen boys were vaccinated. Three months later twelve of them were inoculated with smallpox, but none contracted the disease. At the same time two boys who had not been vaccinated were inoculated with smallpox; both contracted the disease. Virus was then taken from the two boys with the disease and inoculated into the nineteen who had been vaccinated, but still they did not contract smallpox.

Efficacy of Vaccination.

The efficacy of vaccination as a prophylaxis is illustrated on a larger scale by the diagram of Figure 74, showing the death rate from smallpox per 10,000 inhabitants in Prussia, Holland, and Austria. In Prussia vaccination was legally compulsory for all infants, with revaccination at twelve years of age. In Holland vaccination of children was compulsory before they entered school. In Austria vaccination was not compulsory during the times given.

Smallpox is the most widely distributed of all plagues. Nevertheless, nearly one-fifth of all cases reported during 1923-4 occurred in the United States. In most of the states of this country there are laws requiring vaccination, but in many the law is not rigidly enforced. The influence of vaccination in reducing the incidence of smallpox is evident in the comparison of the number of cases in the states of Massachusetts and Minnesota. In Massachusetts vaccination is well enforced, while in Minnesota there is now no vaccination law. During the eleven years between 1913 and 1923 Massachusetts had 457 and Minnesota 53,152 cases of smallpox. The comparison is even more striking when the disparity of population is taken into consideration; that of Massachusetts is 50 per cent greater than that of Minnesota. In 1919 there were 2,002 cases of smallpox in California. The

vaccination law of that state was repealed and in 1924 the number of cases rose to 9,425.

Unfortunately, the contagious virus of smallpox does not respect state boundaries, nor remain where legislation favors it. States which do not have compulsory vaccination and small localities where the enforcement of the law is lax constitute centers from which smallpox may spread. Eradication of the disease

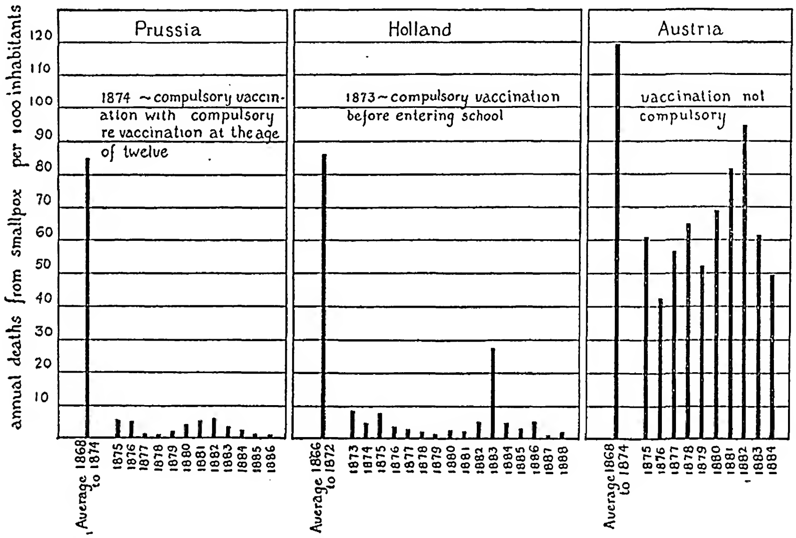


Figure 74. PREVALENCE OF SMALLPOX IN RELATION TO COMPULSORY VACCINATION.

is thus prevented. This circumstance is particularly unfortunate in view of the fact that those who are most commonly killed by the disease—the children—have no part in making the laws.

Alleged Dangers of Vaccination.

The opponents of vaccination allege dangers from vaccination, but these dangers have been greatly exaggerated. Some of these people claim that the vaccine virus is derived from a human subject and that human diseases such as syphilis may be transmitted. This idea may have had some basis a century ago, but in this country vaccine virus is no longer obtained from human beings, but from calves. Calves do not have syphilis, nor any other disease, except the cowpox and tuberculosis, which could be trans-

mitted to man. Tuberculosis is carefully eliminated in the stock used for manufacturing virus. Moreover, both state and federal governments maintain a close supervision and examination of all virus, so as to insure its freedom from contamination. Vaccine virus is an infinitely cleaner product than the purest milk.

Vaccination is not, however, an absolutely harmless procedure. Its danger lies in the fact that a minute scratch is produced in the skin and that this scratch is subject to the same risk that might occur in a scratch from any other origin. Even a pin prick or razor scratch may result in death. Such occurrences are, however, extremely rare. Infections from vaccination result only from lack of cleanliness and neglect. Under modern conditions it is exceedingly rare for death to follow vaccination. The United States authorities vaccinated 3,515,000 inhabitants in the Philippine Islands without a single death or even serious complication.

Tetanus, or lockjaw, occasionally complicates the wound from vaccination just as it may any other wound. Although the tetanus bacilli, or spores, are commonly found in the intestinal tract of cattle and in manure, their presence in virus results only from gross carelessness. The strict government inspection of all virus precludes the possibility of such contamination. Over 31,000,000 doses of vaccine virus were used in the United States during the period 1904 to 1913, inclusive, and only forty-one cases of tetanus followed the vaccination. There were, of course, several thousands of cases of tetanus from ordinary wounds during this same time. The average incubation period for tetanus is from five to ten days. In the forty-one cases of tetanus the average time between the vaccination and the development of tetanus was 20.7 days. Therefore, in the majority, if not all, of the cases the infection was received ten or more days after vaccination. Many of the cases following vaccination gave a history of having the vaccination scab removed in some way, thus permitting an infection of the wound. When the scab reformed the tetanus bacilli were sealed from the air, that being the only condition under which tetanus will develop. Bandages and closed shields also favor the anerobic conditions suited to

the development of tetanus; they should be avoided. This precaution and cleanliness remove any danger from tetanus.

Cowpox, from which vaccine virus is derived, is closely related to human smallpox. Cattle are not subject to smallpox, but when the virus from human smallpox is introduced into the skin of a calf, cowpox results. When smallpox is thus converted into cowpox it remains fixed as such and never reverts to smallpox. The introduction of the material from the skin eruptions of the calf into man results in a local eruption on the skin of the latter. At the same time immunity to smallpox is conferred on the man. Vaccine virus is obtained under conditions of the most thorough cleanliness from the pustule which forms on the skin of the calves. The collected material is mixed with glycerine, ground into a pulp, and dispensed in hermetically sealed tubes.

Vaccination is performed by introducing the vaccine virus into the skin. The skin is first cleaned and then gently scratched with a sharp point until a shallow furrow is produced, but the skin is not cut deep enough to draw blood. The virus is then gently rubbed into the wound. The outer surface of the upper arm is the most common site for the operation although the leg is sometimes selected for cosmetic reasons. The arm is the preferable site, for it is less exposed to injury and infection. The primary wound of the vaccination soon heals. At the end of three or four days one or more small red spots appear. About the fifth day these change to vesicles which are surrounded by a swollen and inflamed area. By the seventh day the vesicle has grown to full size and its contents turn yellow. The skin feels hot and is painful. The axillary lymph glands are swollen and tender. About the ninth day the inflammation subsides and by the twelfth the pustule dries, leaving a brown scab which finally drops off.

Immunity to smallpox appears about the eighth day of the vaccination. The protection is usually absolute for about seven years, and then gradually fades. This fact makes it necessary to revaccinate in order to afford a continuous protection. The best sequence of vaccination is the first year, and again at ten to thirteen years. It is usually unnecessary to vaccinate a third

time unless there is definite exposure to smallpox. All persons known to be exposed to smallpox should at once be vaccinated, unless they have had the disease or have recently been successfully vaccinated.

It is commonly asserted that if revaccination fails to take the subject is therefore immune. Vaccination may fail for many reasons other than immunity. Sometimes persons are unsuccessfully vaccinated three, four, or even more times before a typical "take" is obtained. A person who has once been vaccinated may in very rare cases contract smallpox; but the disease is then of a mild form, the severity depending upon the length of time that has elapsed since the vaccination.

Mumps.

Mumps is a contagious disease of which the main manifestation is inflammation of the parotid salivary gland. This gland is located directly behind the angle of the jaw. The inflamed gland swells and is painful, but pus rarely forms in the gland, and the swelling usually lasts less than a week. Slight fever accompanies the disease, but the constitutional effects are usually mild. Children are not as susceptible to the disease as they are to measles and a more intimate contact is necessary for its transmission. The average incubation period is from seventeen to twenty days.

The disease rarely results in death, and complications do not often follow in young children. In boys, during the adolescent period, and in men, mumps often leads to inflammation of the testicles. In such cases one or both of the testicles may become swollen at about the eighth day of the disease. This complication is particularly liable to occur if the boy is allowed to leave his bed. In severe cases the testicle involved becomes small and is sterile. Usually only one testicle is so affected. But even when both are damaged the sexual virility is as a rule retained. Mumps in women is in rare cases complicated by inflammation of the ovaries.

Whooping Cough (Pertussis).

Whooping cough is a contagious disease characterized by a catarrhal inflammation of the respiratory passages, accompanied

by a convulsive cough which ends in a long-drawn inspiration or "whoop." In late childhood it is a mild disease, but in infancy it is one of the most fatal. Infants are also more susceptible to whooping cough than to any other contagious disease. The disease attacks adults as well as children, and in the aged it is sometimes followed by broncho-pneumonia. One attack usually confers immunity.

The incubation period of whooping cough is from one to two weeks. The onset is gradual. The symptoms at first are those of a head cold with a slight cough. After lasting for a week or ten days, instead of subsiding, the cough becomes more severe. The characteristic attacks of coughing then develop, and vary in frequency according to the severity of the disease. These attacks start with a series of fifteen or twenty forcible coughs, between which the breath is not drawn in. The child becomes blue in the face, and then with a deep inspiration air is drawn into the lungs, making the "whoop" from which the disease derives its name. The child suffers severely during the paroxysm and often vomits afterward.

Whooping cough, particularly for children under five, is a much more serious disease than is popularly believed. The prevention of the disease consists in avoiding contact with those who have it. This avoidance is particularly difficult in whooping cough; many cases of the disease are so mild that the child is able to remain at play, and the period during which the infection may be transmitted varies from six weeks to two months even though the "whoop" has ceased. In mild cases among adults the characteristic "whoop" may not appear at all, but these cases may also spread the disease. Both whooping cough and measles commence with what is apparently a head cold. This reason alone, even apart from the seriousness of colds, should emphasize the danger, especially for children, of contact with anyone with a cold. The older children of a family often contract whooping cough at school, and then communicate it to the baby at home. The older ones recover; the baby is more liable to die. This is a common sequence and one of the chief causes of fatalities.

CHAPTER XXIV

THE VENEREAL DISEASES

SYPHILIS, gonorrhea and chancroid are called the venereal diseases because in the majority of cases they are spread by the contact of venery. The venereal diseases are probably the most prevalent of all the contagious diseases of serious nature; they constituted one of the greatest causes of disability in the army during the European war. These diseases are preventable; but the steps necessary for their eradication are made more difficult by the moral attitude toward them assumed by many otherwise intelligent people. When this attitude is overcome, some difficulty will still remain because the venereal diseases are conveyed by direct contact; it is easier to control diseases which are transmitted by an intermediary host, as is malaria, or which are transmitted largely through objects of common contact, as is tuberculosis. The surroundings under which man lives can to some extent be regulated, but a man's own actions are not so easily controlled.

Origin of Syphilis.

Syphilis was unknown in the civilized world before 1493; soon after 1495 it had spread throughout Europe in a great epidemic; since then it has existed everywhere. Syphilis was probably brought to Europe by the sailors of Columbus on the first voyage to Hayti. The parasite causing syphilis is similar in character to others which cause tropical diseases. In 1494 some of Columbus's returning crew accompanied Charles VIII of France in the invasion of Italy. The epidemic of syphilis began at this time in Italy and spread quickly over Europe with the disbandment and scattering of the troops. Since that time the disease has gone to every corner of the world.

Syphilitic Infection.

Syphilis is an infection caused by the Treponema palladium or, as it is sometimes called, the Spirocheta pallida. It was dis-

covered in 1905 by Schaudinn of the University of Berlin. The organism is a minute animal parasite, not a bacterium, but a protozoan; in appearance it resembles a slender thread bent into the shape of a corkscrew. A powerful microscope with special illumination is necessary to see it.

The organism invades the body through the surface; it enters minute wounds in the skin and can apparently enter unbroken mucous membrane and the modified skin that covers the glans of the penis. After two or three weeks a chancre forms at the point of entry of the organisms. The chancre is a small hard elevation in the skin or mucous membrane with its top cratered by an ulcer. This chancre marks the primary stage of syphilis.

The secondary stage follows in six to twelve weeks. It results from the spread of the parasites from the chancre and their dissemination throughout the body. The effects produced are variable; the lymph glands swell, there may be eruptions on the skin and mucous membranes of the mouth and nose; there may or may not be fever. As a rule, neither the primary nor the secondary stage causes sufficient illness to keep a man from his work. The skin eruption, which is one of the features of the secondary stage, does not show any definite characteristics by which syphilis can be certainly recognized; it may resemble the eruptions which occur in other diseases of the skin. The eruption on the mucous membranes, so called mucous patches, appear as raw areas.

The organisms are present in the chancre of the primary stage and in the mucous patches of the secondary stage. Infection of another person may result from contact with either of these areas. The infection from mucous patches may be transmitted in kissing; the author saw a case in which a young girl, burned on the cheek by the cigarette of her companion, developed a chancre in the burn after he had "kissed it to make it well." The transmission may be effected also from articles of common contact—the use of spoons, glasses, pipes, etc., which have been recently in the mouth of a syphilitic. The organisms are present in the blood and may be transmitted through the use of razors and unclean dental instruments. The organism causing syphilis is frail, but it may live for hours on a wet surface.

The secondary stages of syphilis gradually subside even without treatment. The disease may then seem to have disappeared, but unless proper treatment has been applied the organisms are still engaged in their destructive work in the body. The evidence of this destruction may not appear for many years after the primary and secondary stages. This third stage of syphilis results in the formation of growths, each called a gumma, which may occur in any organ or tissue of the body. Disturbance of functions results corresponding to the organs affected. A common location for the syphilitic changes is in the arch of the aorta; aneurism follows. These changes may extend to other arteries and cause them to harden prematurely. The stomach, kidneys, liver, pancreas, or other organs may be the seat of a gumma. Its occurrence in the wall of the heart may lead to heart block. If a gumma forms in or near the skin an open sore results; if in the nasal passages the septum of the nose may be destroyed and the bridge of the nose depressed. Syphilis may also invade the nervous system. There it causes two types of disease, depending upon the location of its action; in the spinal cord it results in locomotor ataxia and in the brain in paresis, a form of insanity which affects nearly a fifth of the inmates of asylums.

There is no immunity from syphilis; everyone is susceptible, but the severity of individual cases varies greatly. One attack of syphilis does not confer immunity from a second; a primary sore will not develop so long as the organisms remain in the body, but when they have been eradicated by treatment, reinfection may occur just as in a person who has never had the disease. The belief held at one time that the disease conferred immunity was due to the fact that the cures were not complete.

Syphilis and Length of Life.

Untreated syphilis shortens life, owing to the changes occurring in the third stage. Syphilis kills slowly, and the immediate cause of death depends upon the organ in which the destructive changes have occurred; death may result directly from such conditions as apoplexy or chronic nephritis. The shortening of life by untreated syphilis is indicated by the fact that most life insurance companies refuse to accept syphilitics. Syphilis is one of the

chief causes of death in early adult life in persons who appear healthy.

The extent to which syphilis is prevalent is uncertain; estimates made from various sources indicate that between 5 and 20 per cent of the population have or have had the disease.

Congenital Syphilis.

Syphilis is not hereditary in the sense that it is transmitted in the germ cell; but it may be acquired by the fetus in the uterus prior to birth. The infection occurs only when the mother has the disease; the organisms in her blood pass through the placenta and into the blood of the child. In most cases of infection of this kind, the fetus dies in the latter months of pregnancy, a still-born child. Some children survive, and exhibit the symptoms of syphilis; they do not develop normally and they may become insane. They may also be treated and cured.

Treatment of Syphilis.

Even in the early days of syphilis in Europe, mercury was used as a treatment. This metal tends to check the disease; it hastens the disappearance of the secondary stage, but by itself alone it rarely effects a cure, for the organisms are left in the body and the third stage develops later. Benvenuto Cellini in his memoirs gives an interesting account of the ravages of health, seemingly far worse than syphilis, caused by physicians giving excessive doses of "quack silver"—now called quicksilver, or mercury. The name quack has persisted in medical parlance.

A really effective cure for syphilis was discovered by Ehrlich in Germany. He developed an organic arsenical drug known as 606, salvarsan, or arsphenamine. This drug is injected into the blood. It kills the organisms; its use is usually combined with that of mercury or bismuth. Syphilis is one of the few diseases really curable by drugs. The earlier in the course of the disease the treatment is given, the more satisfactory are the results, for damage to internal structures caused by the disease cannot be repaired. Treatment over a period of about two years is required before it can be said with assurance that the disease is cured.

The Wassermann test for syphilis has greatly assisted the treatment, for without this test it is often difficult to diagnose syphilis correctly or to tell when it is cured. The test is made on the serum of blood drawn from the patient; in many hospital wards a Wassermann test is made on all patients, whether or not they show any indication of having syphilis.

Prophylaxis of Syphilis.

The site of infection in syphilis resulting from sexual contact is usually on the glans of the penis or under surface of the prepuce, and not, as in gonorrhea, in the urethral passage. The measures used to prevent gonorrhea will not prevent syphilis. Prophylaxis against syphilis is accomplished by applying over the entire penis an ointment containing 33 per cent of calomel, within one hour after the exposure.

Gonorrheal Infection.

Gonorrhea is a very ancient disease, but the organism causing it, the gonococcus, was not discovered until 1879 by Neisser. Gonococci are bacteria; they are oval in shape and usually found in pairs. The gonococcus can attack only mucous membrane; its point of entry in the male is usually the urethral canal and in the female the wall of the vagina or the cervix. Gonorrheal infection of the eyes is discussed in Chapter XVI as the common cause of ophthalmia of the newborn.

Gonococci placed on mucous membrane do not remain on the surface, but penetrate to the connective tissue beneath the mucous membrane. There they multiply rapidly, setting up an acute inflammation. Pus is formed. The mucous membrane is eroded in spots. The pus then flows from the surface, carrying with it many of the gonococci. These effects appear within two to fourteen days after infection, usually within three to five days.

Gonorrhea in Men.

In men the inflammation of the urethra causes severe pain at the time of urination; in women the effects are frequently unobserved. The course of the disease and the complications which may result from the inflammation also vary in the two

sexes because of the differences in anatomical structure. In the male the gonococci and the inflammation spread up the urethra. In favorable cases the disease stops at the valve of the urethra and only the lower part of the urethra is involved. More often the infection passes to the upper urethra. The inflammation may extend into the ducts leading to the prostate gland, the seminal vesicles, and vas deferens, or it may pass into the bladder or even up to the kidneys. The extension into the vas deferens results in inflammation of the epididymis; and if both sides are affected sterility may result when the disease heals, from the tubes being shut off by the formation of scars.

Under proper treatment gonorrhea in the male can be cured. To do so requires the highest medical skill. Too often the man who is infected regards the disease lightly and is careless in his choice of a physician. Poor treatment results merely in arresting the acute stages of the inflammation, but leaves a chronic infection. The man is then still capable of transmitting the disease; the foci of infection may become active at any time and reëstablish acute inflammation. It cannot be emphasized too strongly that the outcome of gonorrheal infection depends upon the medical skill exercised in the treatment.

Gonorrhea in Women.

In the female the gonorrheal inflammation started in the vagina may progress into the mucous membrane of the uterus. When centered there it usually gives rise to no noticeable effects. Conditions during the menstrual periods aggravate the disease. It spreads farther and passes into the Fallopian tubes and through them to the peritoneum lining the abdominal cavity. The inflammation of the tubes often causes them to be closed by the formation of scars; sterility results. If both ends of a tube are thus closed pus cannot drain from the tube. It becomes distended from the collection of pus, a "pus tube." Pain in the abdomen, fever, and other signs of infection result. It is necessary to remove the infected tube by surgical operation. Gonorrhea is difficult to treat in women and frequently runs a prolonged course.

Gonorrheal Rheumatism.

Although gonorrhea is primarily a local disease, the gonococci occasionally spread into the blood. The infection is then carried to the joints; a very severe form of inflammatory rheumatism results. In these cases the infection may also involve the heart, causing endocarditis, and may lead to valvular disease.

Prophylaxis of Gonorrhea.

Prophylaxis against gonorrhea is largely limited to the male; it consists in washing out the urethral canal with an antiseptic as soon after exposure as possible. The antiseptic most often employed for this purpose is one of the colloidal silver salts such as argyrol. This prophylaxis does not prevent syphilis.

Chancroid.

Chancroid, or soft chancre, is an ulcer which occurs on mucous membrane or skin as the result of infection by the bacillus of Ducrey. The ulcers erode the tissues and are painful. The disease is usually transmitted by sexual contact. It develops within a day or two after infection. It is prevented by ordinary cleanliness, washing with soap and water.

Attitude Toward the Venereal Diseases and Sex.

This chapter is short, but the topic which it treats is one that stands apart. It has too long been viewed from a theologicomoralistic standpoint. So long as action was founded on that standpoint nothing was achieved to decrease the ravages of the venereal diseases, either upon those who were regarded as "sinners deserving punishment" or the vast number of those pure wives and innocent newborn children who were thus "punished for the sins of others." Only as the matter has come to be viewed as a public health problem, and one to be treated apart from moral implications, like any other public health question, has real progress been made. The treatment of sex functions and reproduction has, therefore, in this book been kept apart from mention of venereal diseases. The mind of every normal young man or woman is inspired by a natural and proper interest in those functions which underlie the noblest and most beautiful of human relations, marriage and parenthood.

The educated class in America has an extremely low birth rate; it is almost a dying race. It includes an abnormal proportion of the unmarried and the childless, with the stunting and perversion of character which the lack of a family so often involves. Particularly for such a race the conception of normal sex relations should not be perverted by the implication, too often conveyed, that sexual functions are merely the initiators of disease.

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